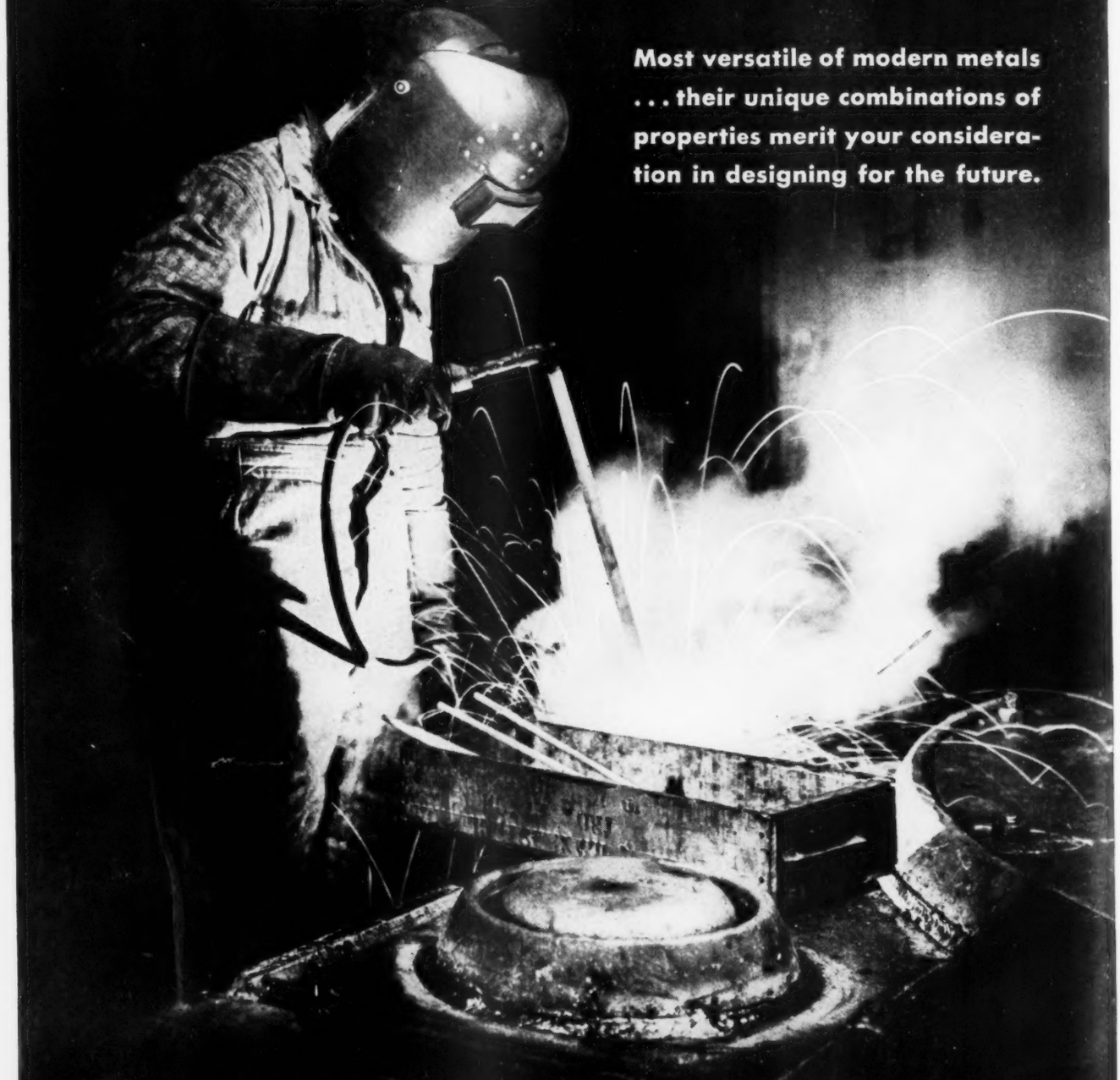
PRODUCT ENGINEERING

JULY, 1946

In this Issue: **Design Features of the 1947 Studebakers**

CHROMIUM-NICKEL AUSTENITIC STAINLESS STEELS



Most versatile of modern metals . . . their unique combinations of properties merit your consideration in designing for the future.

STAINLESS STEEL ARC WELDING ELECTRODES containing Nickel are used extensively for joining heavy alloy steel plates to avoid brittleness in the weld. Here an operator is using a half inch stainless steel electrode in such a welding operation.

International Nickel are miners, smelters, and refiners of Nickel, an important ingredient in the chromium-Nickel austenitic stainless steels. Although they do not produce these stainless steels, a list of the sources of supply will be furnished on request.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET, NEW YORK 5, N. Y.

Die casting for large field telephone set.

GERMAN Die Castings

Made by Hot Shot Gooseneck Method

J. R. TOWNSEND
Bell Laboratories, Inc.

Remarkable die castings discovered by an American commission surveying German industry lead to a search for the machines that manufactured them. The author, a member of the committee, describes the machines and the qualities of the castings.

AN EXHAUSTIVE SURVEY has been made of the German industry by American engineers and scientists. This broad study, in which the War Production Board and other civilian agencies of the Government have been cooperating with the Army and Navy, has included not only developments and production methods in both consumer and durable goods industries of all kinds, but has also covered the layout, construction, operation and administration of electric, gas, communication and transportation systems. The experts making these investigations have been drawn largely from American industry and nearly 250 have spent considerable time in Europe in connection with this work. Mr. L. H. Peebles, Director of the W.P.B. Communication Division has represented the W.P.B. on the Communications Committee and has been its Chairman. The writer made a trip to Europe as a member of this committee to investigate German communications systems and equipment.

Captured German wire and radio communication equipment exhibited rather remarkable aluminum and magnesium die castings used for the chassis and framework of instruments and other apparatus. The die castings are remarkable not only in size and intricacy but also in their freedom from blow holes and surface defects. So unusual are these castings that it was obvious that the knowledge of the method of their manufacture would be of considerable interest and value to both the Signal Corps and the communications industry as a whole. Accordingly, the manufacture and process by which these castings were produced was made a target for investigation.

After visiting several die casting plants in Germany, the source of these castings was found to be the Mahler Werke of Fellbach, near Stuttgart. On July 29, 1945 a team composed of Messrs. R. H. McCarthy, P. Mertz and J. R. Townsend, visited the plant. A report of this investigation has been submitted to the Govern-

FIG. 2

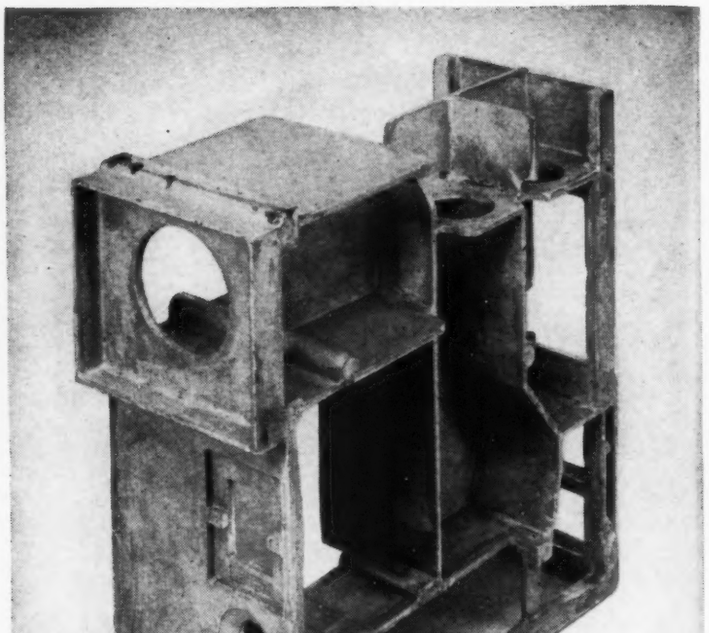


FIG. 3

Fig. 2—Vertical die casting press being erected.

Fig. 3—(Above) Die casting for radio chassis.

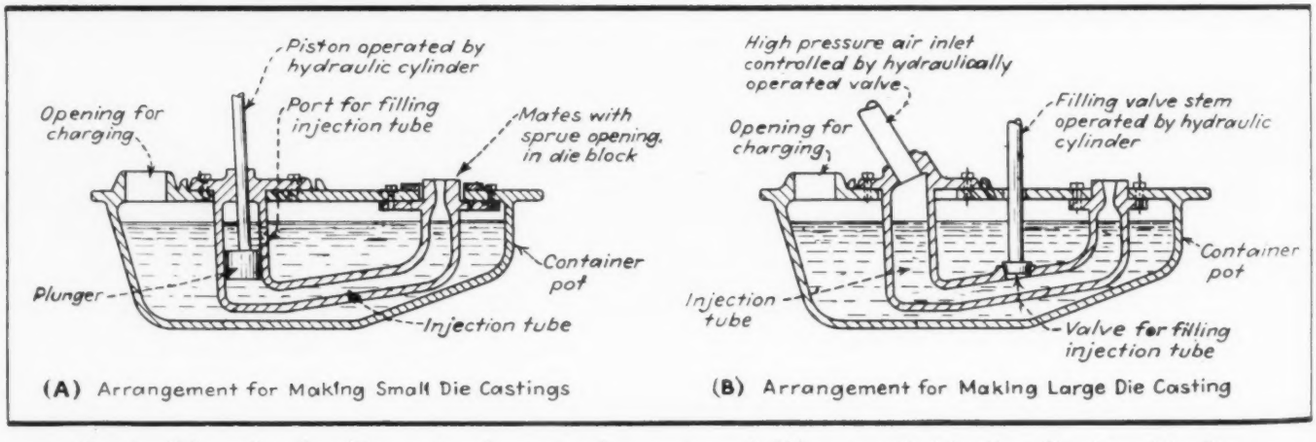

Piston operated by hydraulic cylinder
Opening for charging
Port for filling injection tube
Mates with sprue opening in die block
Container pot
Plunger
Injection tube
(A) Arrangement for Making Small Die Castings
High pressure air inlet controlled by hydraulically operated valve
Opening for charging
Filling valve stem operated by hydraulic cylinder
Container pot
Injection tube
Valve for filling injection tube
(B) Arrangement for Making Large Die Casting

Fig. 4—Schematic of melting pot and gooseneck arrangement, (A) pneumatic injection, (B) piston injection.

ment and is now available through the Superintendent of Public Documents as Report C-28, Mahler Werke GmbH, Fellbach.

The Mahler Werke manufactured die cast parts for gas masks, bombs, fuses, radio telephone sets, field glasses, cameras and similar equipment. They specialized in large complicated die castings such as for field telephone sets and radio chassis. The plant is very modern, with an excellent tool department normally employing 120 mechanics, and is equipped with 40 die casting machines of which 20 are conventional Polak machines and the balance are machines of their own design. During the war, the plant employed about 1,000 people and produced 50,000 die castings per day, working two 12-hour shifts. Sixty to 80 small field set castings and 30 of the large ones were made per hour per machine.

The die casting machines of their own design were vertical presses with the metal injected from bottom of the stationary lower die. The upper die travelled vertically, the die opening was horizontal. Thus, the metal was forced up vertically and spread out horizontally to fill the mold. Elaborate tooling was used with special forces for opening dies, ejecting castings, and removing cores. In Fig. 2 is shown one

of the twenty vertical presses being erected. Each machine is in a separate room and the operating controls just outside the room.

The machines are designed to produce "hot shot" aluminum and magnesium die castings. The gooseneck is mounted in a cast steel body in the die casting machine. The metal is ejected from the body by one of two methods; for the small die castings by a plunger type piston and for the large die castings compressed air is used. In Fig. 4 the plunger type is shown at (A) and the air pressure type of gooseneck is shown at (B).

The body is filled by cold charging through the large rectangular slot as indicated in Fig. 4. A clamping force of 300 atmospheres is used on the die closure and the gooseneck injects the hot metal into the die under an air pressure of 100 atmospheres or 1,500 lb. per square inch.

Rather complicated tools are used with elaborate forces and with pressure cylinders to pull cores and to separate the dies.

The equipment was thought to be remarkable in that here was a successful process for the manufacture of magnesium die castings by the hot charge method. The use of 1,500 lb. per sq. in. air pressure presents some hazards. It was observed that there had been spitting of metal around the room inclosures and there were rumors of accidents having occurred in the plant. However, this method of making hot charge die castings is worthy of further study and it is believed that engineering design can overcome some of the hazards.

Reproduction of x-ray film made of the casting for a small field telephone set is shown in Fig. 6. This casting was taken at random from a pile of castings found in the plant. The x-ray examination shows the remarkable freedom from blow holes and other imperfections. It was noted that very small gates were used and it is probable that the high pressure and high velocity of the metal accounts for it arriving in the die in a fluid state and completely filling the mold before freezing began.

It was recommended to the Government that one of these machines with suitable dies be sent to the United States for study and investigation. Such a machine is now on the way to America.

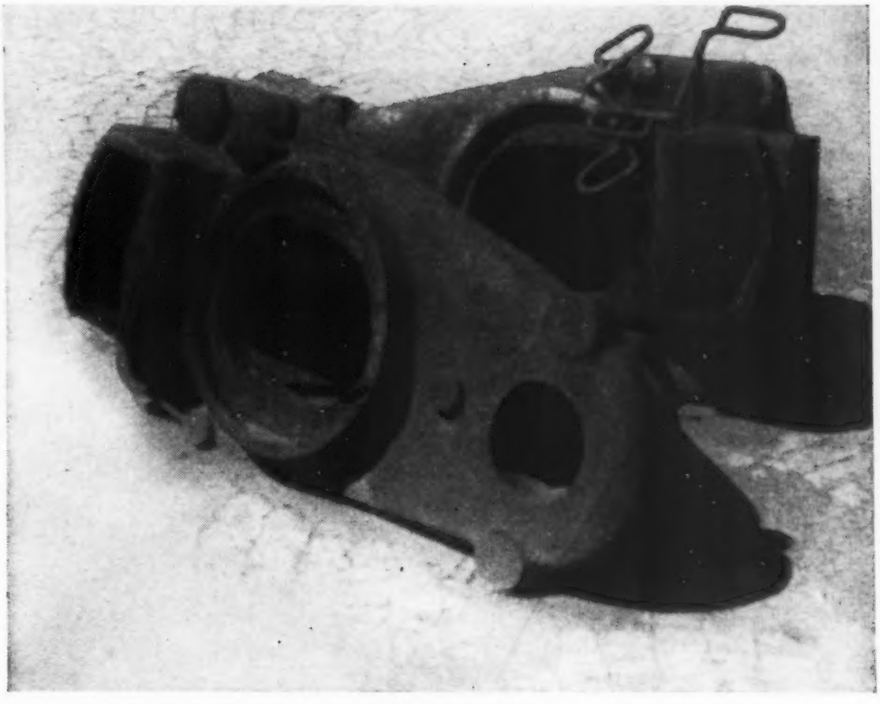
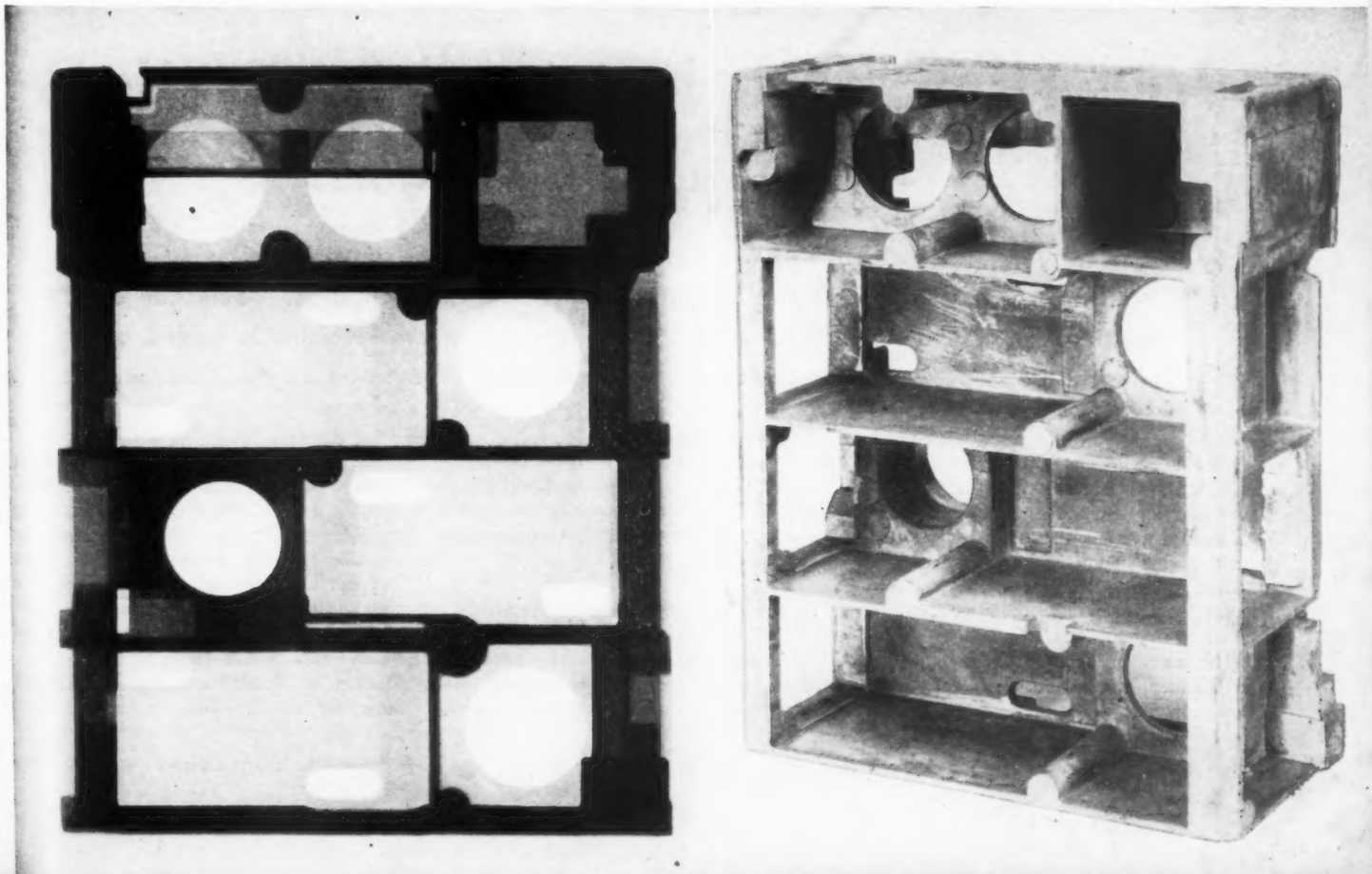


Fig. 5—Top view of melting pot for housing gooseneck.

Fig. 6—Die casting for small field telephone set and x-ray of it showing its remarkable freedom from imperfection.



Urea-formaldehyde resin adhesives being used in production of musical instruments

The Fred Gretsch Company

Thermosetting Adhesives for Wood Properties, Techniques and Applications

PRESCOTT C. FULLER and ROBERT L. HILLER
American Cyanamid Company

Working and cure characteristics of synthetic thermosetting adhesives. Selection of the proper adhesive for both plywood manufacture and assembly gluing is guided by physical properties and chemical resistance. Applications of plywood are also discussed.

Adhesives based on synthetic resins can be divided into three categories: thermoplastic, thermosetting and rubber-like. For bonding wood and plywood, thermosetting adhesives are the most important. Although they are derived from the thermosetting resins, which require heat for curing, several of them can set at room temperatures.

Thermosetting synthetic resin glues can be divided into four general types: Urea-formaldehyde, melamine-formaldehyde, phenol-formaldehyde, and resorcinol-formaldehyde. Each type has modification developed for specific manufacturing conditions and the ultimate service requirements of the finished product.

Urea-Formaldehyde Adhesives

Urea-formaldehyde resins are produced by the reaction of urea and formaldehyde with a catalyst under controlled temperature conditions. These resin adhesives are available in three general forms:

1. As a pure spray-dried resin containing no filler or extender. Such materials are approximately 99 percent pure resin when shipped. They remain stable for at least six months when stored in a cool-dry place. The resin is mixed with a catalyst, filler and water when it is to be used.

2. As a liquid dispersion, consisting of about 70 percent solids. It has the disad-

vantage, compared with spray-dried material, of being supplied in a barrel having a total weight of more than 500 lb.; the problem of handling and disposing of the barrel presents difficulties. This product is also mixed with a catalyst, filler and water.

3. Spray-dried resin adhesive, containing filler of up to 20 percent of the resin weight and, in some instances, a catalyst. Water and additional filler, and in some products, catalyst are added when the adhesive is used. It is supplied as a powder.

Filler, spray-dried, urea-formaldehyde adhesive rather than pure resin is preferred by some users because it is claimed that resins containing fillers such as walnut shell or wood flour tend to cake when stored for long periods of time. Another reason advanced is that a filled resin will give better strength values than a pure resin used without filler. When these pure resins are properly manufactured, however, they have a storage life equivalent to that of filled resins.

At present, there seems to be some basis for questioning the belief that a resin has to be "extended" to obtain maximum wood failure. Wood failure expresses the ability of a shear sample to fail in the wood rather than at the bend. On soft, porous woods such as pine—where there is a tendency for the adhesive to soak into the wood, leaving a "starved" joint—there seems to be some advantage in the use of a filled material in which the filler will retard penetration. On the other hand, with dense woods such as maple and birch, the fact that the unfilled resin cannot penetrate into the wood is of some advantage. It is also advantageous, from the cost standpoint, to buy a pure resin—liquid or powder—and add a filler at the time of use. Common filler such as wheat flour, walnut shell or wood flour, cost approximately one-fifth as much as resin.

Although extension by flour reduces the price of the adhesive, adding too large a volume of extender reduces the quality of the bond produced. The quality of bond produced can be varied from one that is slightly better than tapicoa, to a highly water-resistant union.

By exercising care in the selection of resin adhesive and catalyst, the urea-formaldehyde type of adhesive can be adapted for wood bonding at temperatures from 70 to 300 deg. F.

Urea-formaldehyde adhesives that are not unduly extended show high initial dry strength, good resistance to soaking in cold water and to alterately high and low humidity conditions. Urea-formaldehyde joints will decrease in strength when exposed to continuous low humidity and high temperatures. Such decreases in joint strength appear to be related to the strength of the species of wood that is bonded. Soft woods, such as pine, will show somewhat less reduction in shear strength than hard woods like birch or maple.

A special type of "craze-resistant" urea-formaldehyde resin adhesive has been developed specifically for assembly type gluing. During the war, the British producers of wooden aircraft were faced with the problem of finding a satisfactory water-resistant glue for assembly work. After much experimentation, they succeeded in developing an assembly adhesive that was basically urea-formaldehyde, but modified to eliminate the crazing or cracking of the glue structure that occurs in conventional urea-formaldehyde adhesives when the glue line thickness is greater than 0.008 inches.

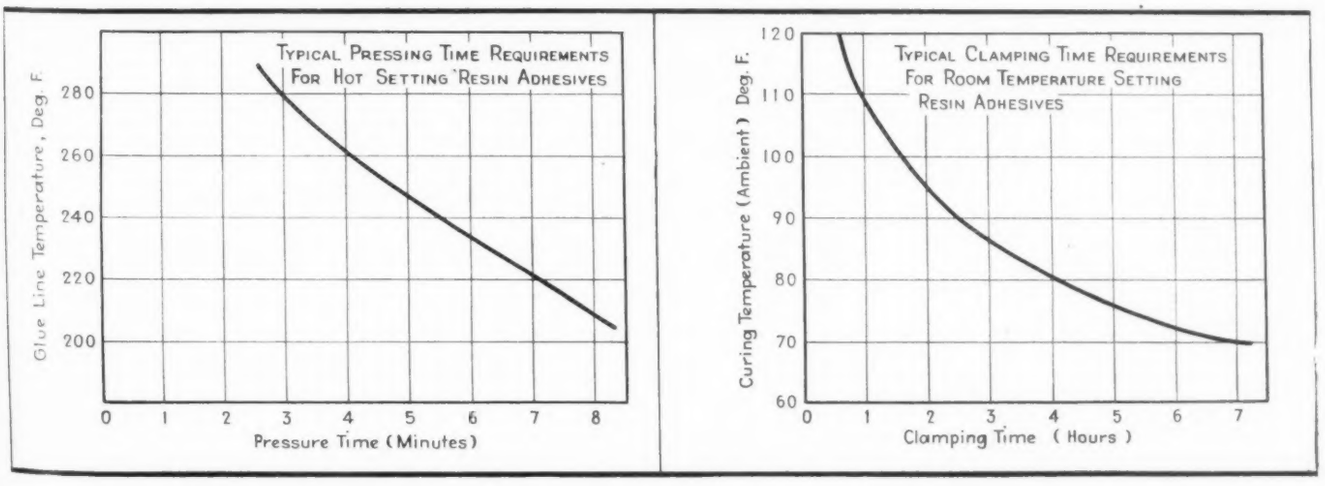
Since the war, this urea-formaldehyde type of assembly adhesive has been improved and now enjoys wide acceptance by the wood-working industry. It is essentially a cold setting resin adhesive, although heat will materially speed the cure time. This assembly adhesive possesses good water resistance, makes a bond of excellent durability, and will not crack or craze even when glue lines up to 0.020 in. in thickness are necessary.

Melamine-Formaldehyde Adhesives

This resin was introduced as an adhesive about 1940, although it was previously used for paper laminates. As a wood working adhesive, melamine-formaldehyde is usually available either in the form of a pure resin or a resin with incorporate filler. It is normally

Gillespie Furniture Company

Plywood aircraft gas tanks of 310 gal. capacity were produced with melamine-urea formaldehyde resin adhesives.



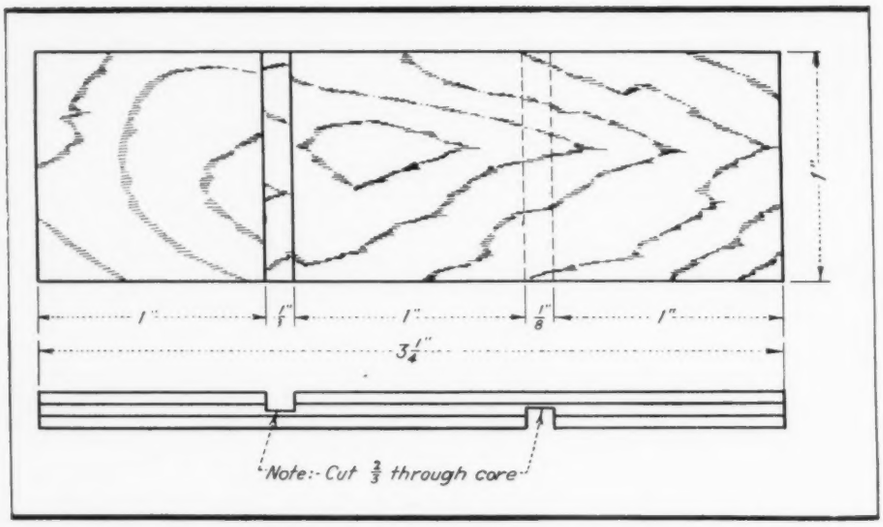


Diagram of plywood shear test specimen.

sold in powder form. The material is hygroscopic and soluble in water and water-alcohol solutions. Melamine-formaldehydes, in its pure state is white and, if used without filler, will give a white glue line. Working characteristics are similar to phenolic adhesives. It has an advantage over some of the other adhesives in that the working life (pot life) is between 2 and 48 hours. Assembly time (period between spreading glue and pressing panels) can be prolonged for more than a week if the material is kept at room temperature where the air has from 7 to 9 percent equilibrium moisture content.

Most of the melamine-formaldehyde adhesives curt at temperatures above 200 deg. F., although with the addition of the proper catalyst, cure can be obtained at temperatures of 140 deg. F. Such low temperature cures, however, prolong setting time.

Melamine-formaldehyde resins are being used extensively for the fortification of urea adhesives, and show a remarkable ability to increase shear strength and wood failure values of ureas even when added in small amounts. For instance, if only 5 percent melamine-formaldehyde is added to the urea-formaldehyde adhesive, the resulting bond has been known to give 100 percent wood failure when tested after 24 hours soak at 75 deg. F. This ability to increase durability of urea bonds is better shown when bonded samples are boiled. Although urea-formaldehyde bonds will delaminate completely when put in boiling water for three hours, the addition of 5 percent melamine-formaldehyde will produce a bond that remains intact, and will give shear strength values of 125 lb. per sq. in. Values of better than 280 lb. per sq. in. are produced with the addition of 15 percent urea-formaldehyde.

Phenol-Formaldehyde Adhesives

Phenolic type adhesives can be divided into two general groups: High temperature setting. (260 to 320 deg. F.), and low temperature curing, which require temperatures between 120 and 180 deg. F. The latter, which are modified phenolics, require a much longer cure time.

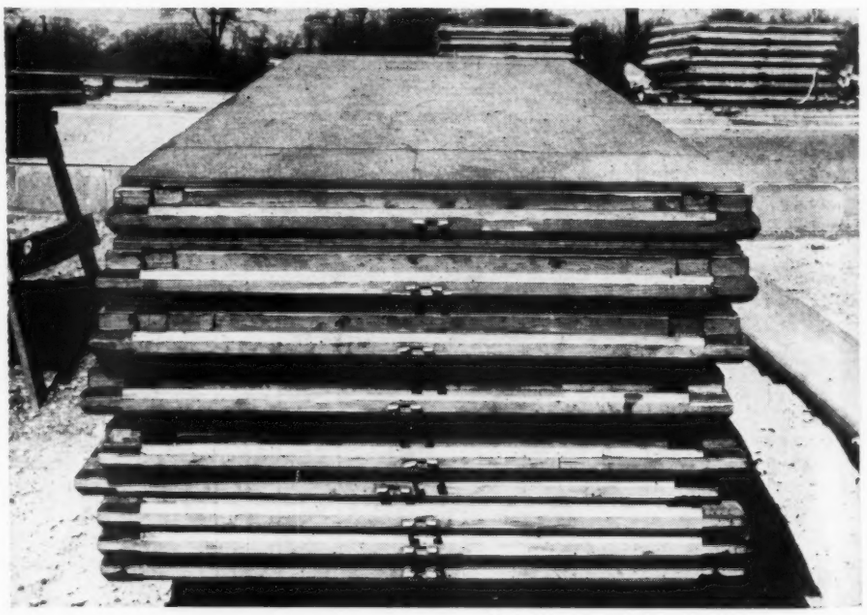
One form of phenolic type adhesives is an impregnated paper, called a phenolic film. This type of adhesive is cut to the size of the assembly on the job. Assembly operations can be prolonged for weeks without deterioration of the adhesive, under the proper temperature and humidity conditions. Phenolic impregnated paper, of which about 30 percent by weight is paper, has a density of about 12.5 lb. per thousand square feet. Curing temperatures for phenolic film type adhesives usually vary from 260 to 320 deg. F.

Phenolic films have several advantages over the liquid types of phenolic adhesives. They eliminate the necessity for mixing and spreading operations, making laying up assemblies easier and prolonger assembly time possible. On thin veneers, this adhesive reduces the possibility of "bleeding." A disadvantage, however, is that on rough-cut veneers two sheets are required, as no moisture is added to the wood. Veneers having less than 6 percent mositure content show dried joints. A moisture content in excess of 12 percent causes bleeding, blisters or "starved" joints. Unless the press is closed immediately after the veneers are placed in it, premature curing is likely to occur.

Phenolics are also prepered as water or alcohol dispersions, and in powder form, where the resin is mixed with the solvent shortly before application. Phenolic adhesives can have either an alkaline or acid reaction, although most of them are alkaline.

Hardeners are usually added at the time of mixing, and thne mixed adhesive has a working life ranging from minutes to hours, depending on the formulation used. Assembly time also can be regulated from a few minutes to over a week. Curing temperatures are about the same as those required for the film type adhesive, and average between 260 and 310 deg. F. During the past few years, considerable work has been completed on extenders such as animal blood and starches, to lower the cost of the gluing operation. Extension naturally affects the durability of the bond and care should be taken in the percentage of extenders used.

Phenolic bonds resist attacks by fugi and bacteria, as well as prolonged soaking in both fresh and salt water. The bond will



Units for prefabricated house. Panels are built up of plywood glued with phenolics and melamines adhesives. Resorcinol glues are used in the assembly of the plywood.

Williams Furniture Company

Urea resin extended with flour is applied to veneers by a glue spreader.

not be weakened below a temperature that will char wood, and therefore can be considered more fire resistant than wood.

Resorcinol-Formaldehyde Adhesives

A comparatively new development in the field of synthetic resin adhesives are the resorcinol-formaldehyde resins. Resorcinol adhesives make it possible to carry on gluing operation at room temperature and to secure bonds equivalent in strength to the hot press phenolics and melamines. Resorcinol adhesives are liquids, with a powdered hardener added at time of use. Curing can be carried out at a temperature of 75 deg. F. and higher.

Although resorcinol glues occupy an important place in wood working, they also have disadvantages. Their cost averages agout three times that of ureas and phenolics. When cured, they are dark in color and are particularly objectionable when penetration into the wood occurs on natural finished surfaces.

Recently, resorcinol-formaldehyde resins have been further modified by the addition of phenol-formaldehyde, thus introducing savings in cost. Present data indicate that these new phenol-modified resorcinol-formaldehyde adhesives are comparable in working characteristics and quality of bond produced to the pure resorcinol adhesives.

Working and Cure Characteristics

Thermosetting resin adhesives can be used with hot or cold press methods. Urea-formaldehydes can be used with either method, melamine-formaldehydes and all but the special low temperature phenolic formulations are only adaptable to the hot press technique, while the resorcinol-formaldehydes are primarily coldsetting adhesives. The methods are classified as follows:

1. *Cold press.* By addition of proper catalyst, the cure can be completed at room temperature.

2. *Hot press.* Elevated temperature, usually between 220 and 310 deg. F. are required for car.

The working life of cold set formulations will vary from 2 to 4 hours at 80 deg. F. assembly time 20 to 30 minutes, curing time 4 to 10 hours. Glue is applied on large double roll spreaders, the plywood assembled and pressed in a hydraulic press. After pressure is applied, retaining clamps are put on the assembly and it is set aside to cure. Cold press plywood requires somewhat heavier spread than hot press, considerably more handling and on the average produces somewhat inferior bonds to those produced in the

Selection of Resin Adhesives for Plywood and Assembly Gluing

Type of Resin Adhesive	Exterior Grade Highest Durability Plywood		High Moisture—Resistant Plywood		Medium to Low Moisture-Resistant Interior Grade General Purpose Plywood	
	Plywood	Assembly	Plywood	Assembly	Plywood	Assembly
Urea-Formaldehyde			x	x	x	x
Urea-Formaldehyde, low flour extender			x		x	
Urea-Formaldehyde, high flour extender					x	
Melamine—Formaldehyde	x		*			
Melamine—Urea—Formaldehyde	x		*			
Phenol Formaldehyde			*			
Resorcinol—Formaldehyde	*	x	*	x	x	*

*Would give good bond, but is costly.

hot press. It does not, however, require as high an investment as a hot press, and plywood can have wider range in moisture content.

Glue formulations used for hot press bonding are adjusted to permit pot life of as much as a day and assembly time even longer. Of interest to plywood manufacturers is the recent introduction of high frequency as a means of curing resin bonded plywood.

Applications

Applications of resin adhesives can be classified according to two general types of production operations: Plywood and assembly work. Plywood is commonly grouped in three categories (see accompanying table on selection of resin adhesives): 1. Highest, or exterior grade;* 2. High moisture-resistant plywood, sometimes known as simply "moisture-resistant" plywood; 3. General purpose plywood called "interior service" or "medium" to "low" moistiure-resistant plywood.

Exterior grade plywood is used for aircraft, marine work and exterior paneling. Douglas fir exterior grade, and such hardwood grades as mahogany, birch, and gum plywood fall into this category.

High moisture-resistant (not "waterproof") plywood finds application in temporary outdoor housing, highest grade furniture panels and boat interiors.

General purpose plywood is self-explanatory. Common applications are containers, interior paneling, flooring, drawer bottoms, table backings and novelty pieces. This material accounts for the greatest volume of hardwood plywood produced.

Tests and Specifications

A quick, short-time test for high-grade plywood that later can be correlated with long time exposure tests has been developed.

Samples are cut 1 in. wide, 3 in. long, slotted from representative panels, and boiled for three hours. They are then pulled in shear. Wet samples must not fail under 280 lb. per sq. in. A minimum shear strength of 340 lb. per sq. in. is also required for dry shear samples. These values are not rigid, and vary with the grade of wood tested.

Army-Navy purchases of high-grade plywood are controlled to a considerable extent by specification AN-NN-P-5116, which is essentially the same as the test outlined in the preceding paragraph.

The Douglas Fir Plywood Association, which is composed of veneer and plywood manufacturers, has adopted Commercial Standard CS-45-38, issued by the National Bureau of Standards. Under this standard, bonding requirements for all the general types of plywood are established. The hardwood plywood industry has adopted, for the "high moisture-resistant" type of plywood, Bureau of Standards Commercial Standard CS-35-42.

Plywood Resin Adhesives

Every type of adhesive is used in the manufacture of plywood, and formulations will differ in almost every plant. For Army-Navy aeronautical specification AN-NN-P-511b, Douglas Fir and Hardwood exterior plywood, phenolics and melamines are used almost exclusively. This is the most durable type of plywood produced and the bond will usually outlast the wood.

Plywood so bonded finds general use in boats, aircraft, and on applications where the finished panel is exposed to the most severe service requirements. Both phenolics and melamines are unaffected by temperatures that will char wood. Another type of adhesive used in the manufacture of this type of plywood is the fortified urea. It has been found that when 30 to 50 percent melamine is added urea conforms to the same tests and service conditions as the phenolics and pure melamines.

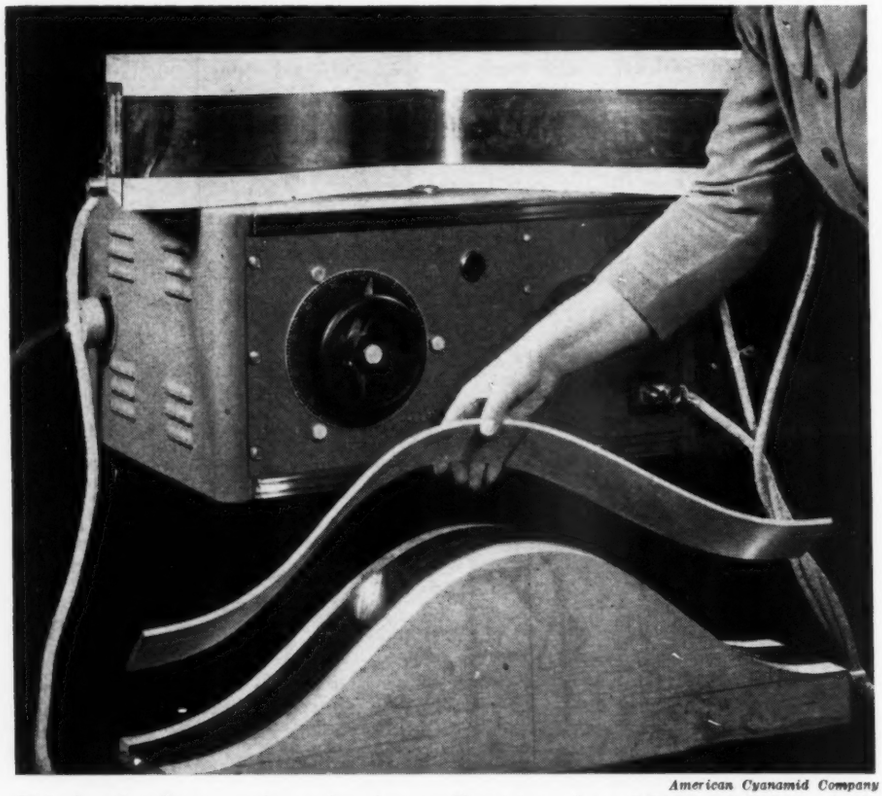
The quality of the glue bond desired is dependent upon the ultimate use. For example, considerable plywood is made with tapioca as the adhesive. This plywood is considered acceptable by some furniture manufacturers as drawer bottoms, where the plywood is not under stress, is well supported, and not subject to any adverse usage. Competing with tapioca for this grade are highly extended urea-formaldehyde resins and adhesives. Formulations are now available whereby urea-formaldelhyde can be extended with flour up to several hundred percent and still give bonds that are more durable than tapioca. It produces material referred to as resin adhesive bonded plywood, and is good for drawer bottoms, but it would not be satisfactory for many other requirements.

Assembly Resin Adhesives

Every resin adhesive has been used for assembly gluing such as joining, laminating or other construction. As long as it is possible to achieve a glue line thickness of not more than 0.008 in., conventional resin adhesives are satisfactory. The two spectacular applications for assembly resin adhesives, developed during the war years, were airplanes and boats.

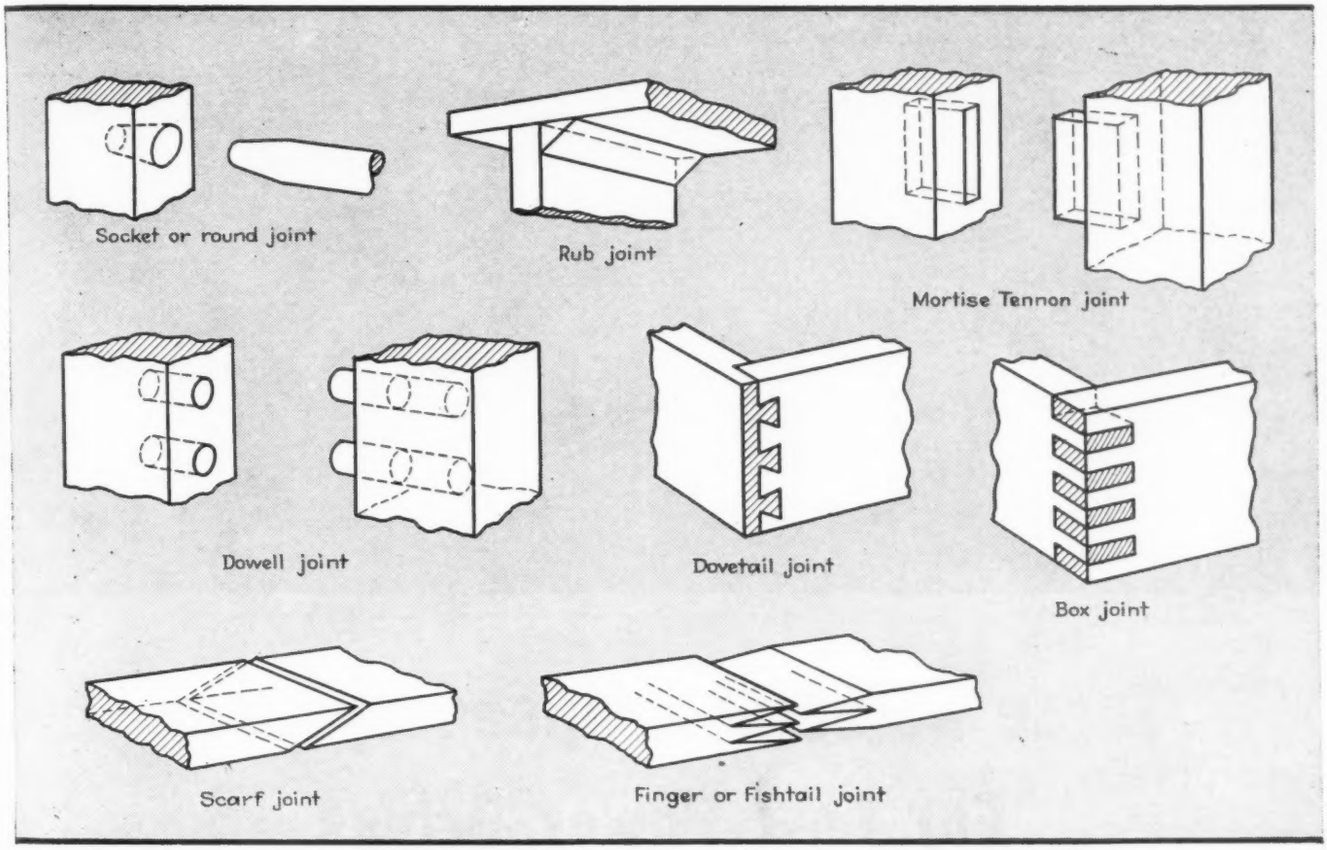
In the United States resin adhesives were used in the construction of the CG-4A Cargo Glider, used in the invasion of Europe. The skin of this glider was made of an phenolic- or melamine-bonded plywood, and the assembly was accomplished with urea and resorcinol formaldehyde adhesives. Ureas were used for heavy beam laminating, for the gluing of ribs, skins, gussets and in other assembly operations.

The new urea-formaldehyde non-crazing adhesives, developed originally for assembly of the British Mosquito bomber, produce a



American Cyanamid Company

Strip heating for curved wooden shapes. Sheet iron, from 0.005 to 0.040 in. thick, is placed in the wooden mold and the ends are brought out for attaching electrodes. A transformer supplies between 5 and 20 volts at a maximum of 230 amperes. This technique is useful for scarf joints in large sheets.



Synthetic assembly resin adhesives of the urea or resorcinol type can be used with all those joints.

glue line up to 0.020 in. in thickness, and possess sufficient water resistance for all but the most severe conditions of outdoor exposure. They are normally cold setting adhesives, and thus can be used with no essential changes in manufacturing technique. They do, however, not cure as quickly as animal glues.

When elevated temperature equipment is available, assembly type adhesive of the craze-resistant type can be cured as rapidly as normal heat setting resins. In addition, there are several special techniques that were designed for these adhesives. One of these is the principle of strip heating. A simple, wooden form is built to the contour of the parts to be glued, and strips of conductive metal are fitted to the mold. In this manner, expensive hot press equipment is eliminated, cure time or clamp time is materially reduced making it practical for a small part of a large section to be locally glued.

An even newer technique is that of conductive rubber heating blankets. Here the expensive transformer—necessary with strip heating—is eliminated, and cure time still approaches that of hot press operations.

Molded and Laminated Plywood

The use of resin adhesives in wooden boat construction during the war consisted of two general applications: Molded plywood hulls and heavy timber laminated keels.

To mold hulls, veneers are cut to the desired shape, spread with melamine or phenolic glue and staples over a male form to conform to the finished shape desired. After all the veneer are laid in place, the assembly is covered with a rubber blanket that transmits heat and pressure to cure the assembly, when placed in an autoclave. When the adhesive is cured, the assembly is removed from the autoclave and is ready for conditioning and finishing. The advantage of this type of construction over the old jointing of boats are: Reduction in upkeep, no caulking required, ease of painting, and considerable reduction in weight.

The experience gained in molding boat hulls is already being applied to other industries, such as radio cabinets and furniture, where molding technique can be used.

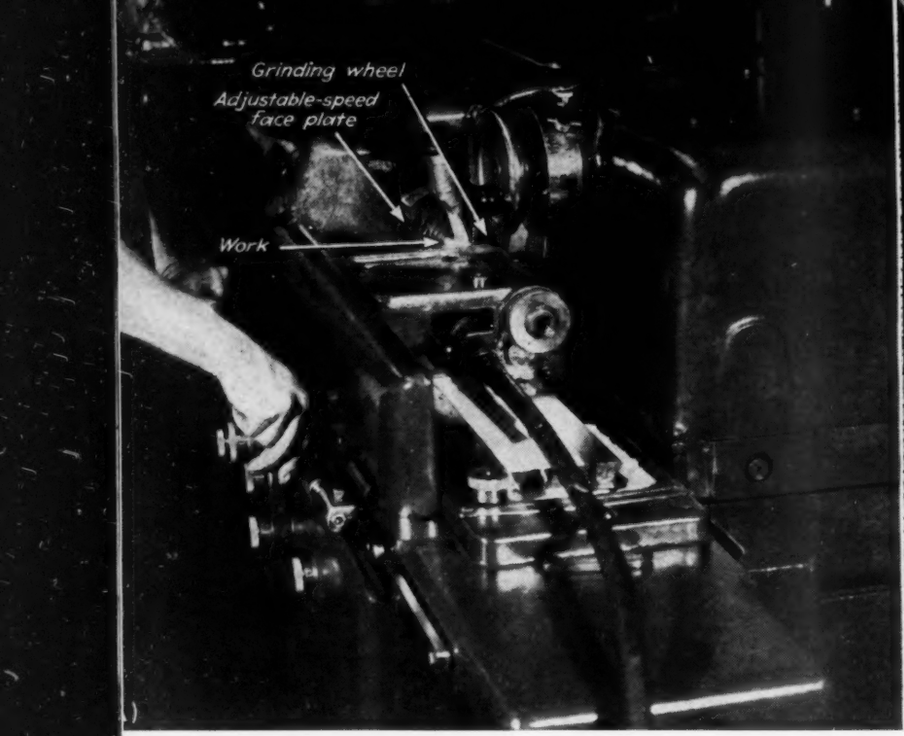
The laminating of white oak boards in the manufacture of keels for boats, and beams and trusses for construction purposes, is another accomplishment of resin adhesives. Casein and blood albumin have been used in the past, but they were not waterproof and there were frequent failures in the joints.

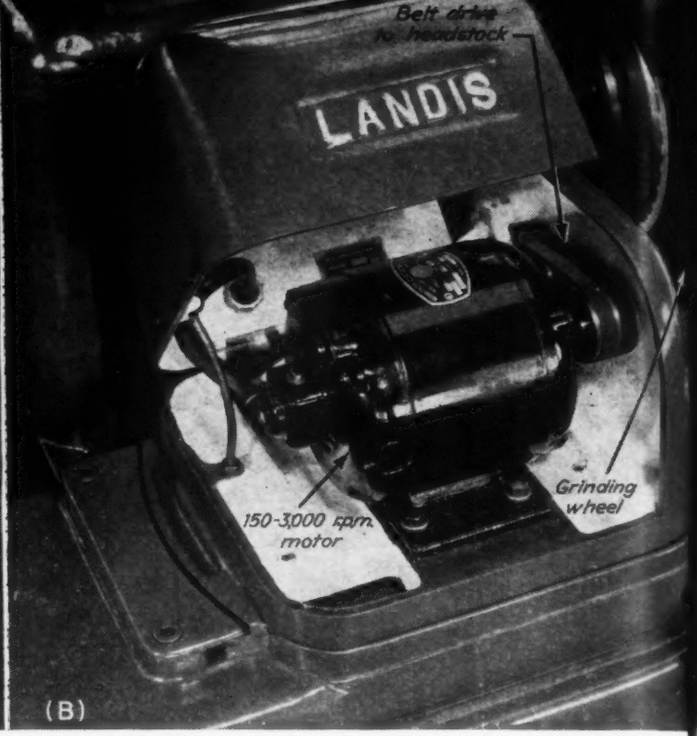
The usual method of laminating is to make boards of desired length by means of finger jointing. In assembling these boards in the jig, the joints are staggered to make a uniform strength laminate throughout. Layers are spread with glue immediately before assembly and built up in the jig, after which pressure is applied. The entire assembly is then pushed into a controlled temperature oven (160 to 200 deg. F.). Other units made by this process are knees, mast steppings, frames, horn timbers, keelsons, shaft logs, side fenders, spars, stringers, tow posts, and transoms.

Advantages claimed for laminations are: (1) Savings in high quality material. Up to 60 percent more use of low grade and short length material can be use; 2. Lower maintenance cost; (3) reduces amount of finishing required in final shaping operations; (4) greater rigidity; (5) more uniform strength characteristics.

The biggest disadvantage of resin adhesives for assembly applications is the lack of initial tack and slow cure cycle. In an effort to reduce cure time and improve initial tack, a technique called "separate application" is being used on some operations. This consists of putting the resin on one wood surface and the catalyst on the other. Another means of accelerating cure which seems to have considerably more promise, is the addition of more catalyst to the adhesive and the maintenance of adhesive temperature of 40 to 60 deg. F. while it is being used.

No attempt has been made in this article to cover the details of handling resin adhesives for specific applications. Adhesives manufacturers supply details that apply to the use of their own particular material.





Three Adjustable-Speed Systems For Low Power Drives

R. S. ELBERTY
Consulting Engineer, New Britain, Conn.

Operation, load characteristics, field of application, and control considerations for three basic types of generator-supplied low power adjustable-speed drives are discussed. Separately-excited, self-excited, and compound-excited systems are analyzed and compared.

THERE ARE several generator-supplied electrical drives for auxiliary machine motions that provide many operating advantages such as adjustable speed and automatic control.

In general, since the horsepower requirements are small as compared to the main drive, the d.c. generator may be driven from the main drive motor thus providing an economical source of power for the adjustable speed drive. For such applications, some type of V-belt is a convenient way to drive the generator at its correct speed regardless of the particular constant speed of the main drive motor used on the machine. The electrical characteristics of these low power drives are easily standardized to be independent of the electrical power supply in the customer's plant. Once standardized, for economy, motors and generators can be carried in stock for application to new machines and for replacements.

In applying the drives, the rotating machines and control should be accessible and never buried deep in a machine. In moist atmospheres, the motor should not be oversize. A warm motor is usually a dry one. With fractional horsepower drives, motor heating is rarely a limiting factor, hence totally inclosed motors are often good investments on these applications. A typical installation using a fractional horsepower auxiliary drive is shown in Fig. 1, and illustrates good application practice.

The three types of systems ordinarily considered for low power drives are:

1. Separately-excited, adjustable-voltage drive.
2. Self-excited system using series-wound machines.
3. Compound-excited system that is a combination of the other two drives.

Each has certain operating characteristics and economic considerations influence the selection for any given application. Good speed regulation of about five percent can be obtained with these d.c. drives, but exceptionally precise speed control requires a special speed regulator. The relative advantages and limitations of these three drives follow:

Separately-Excited Drive

As shown in Fig. 2, the adjustable-voltage, or Ward-Leonard system, consists of a d.c. generator, a d.c. motor, and an exciter that furnishes excitation.

A separately-excited generator driven at a constant speed will deliver a voltage that remains substantially constant with a variation in load. The excitation on the field is adjusted to control the voltage supplied to the armature of the driving motor. There is a slight reduction in the generator voltage as load is applied because the circulating load-current causes an *IR* voltage drop in the generator. For a given load-current, the loss in voltage remains the same since the resistance is constant. To reduce the speed

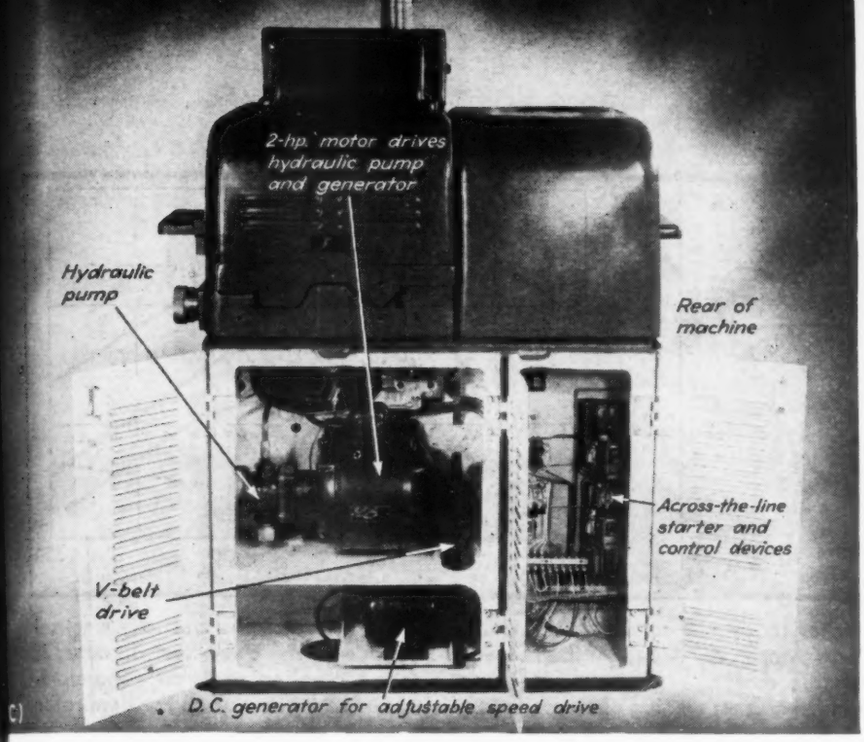

2-hp. motor drives hydraulic pump and generator
Hydraulic pump
Rear of machine
Across-the-line starter and control devices
V-belt drive
D.C. generator for adjustable speed drive

Fig. 1—Machine tools are typical of products requiring some type of adjustable-speed drives. (A) A simple, compact, series variable-voltage auxiliary drive is used on this Landis Tool Co. grinder. (B) A totally inclosed 1/3 hp. series motor, rated constant-torque 150 to 1,800 r.p.m. and constant-horsepower to 3,000 r.p.m., drives the faceplate which is the only other moving part. (C) The generator is belt driven by hydraulic pump motor, that is controlled by the a.c. across-the-line starter in the compartment at the right.

Fig. 2—Basic circuit for separately-excited adjustable-voltage control. Rheostat R_1 controls motor speed by controlling generator field strength to vary the armature voltage. For speeds higher than maximum armature voltage will produce, the motor speed is increased further by weakening motor field by increasing resistance R_2.

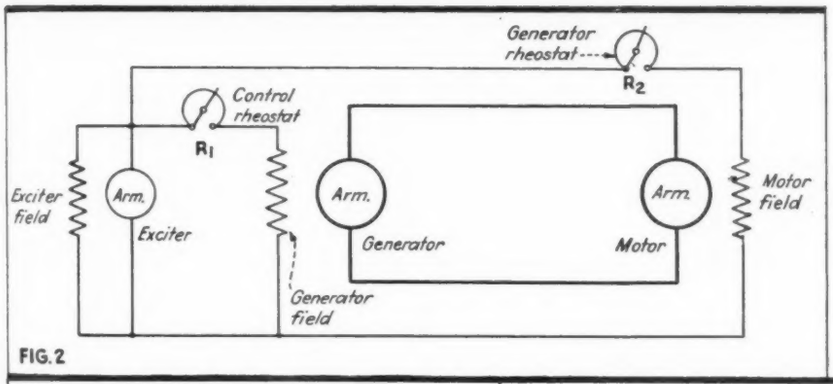


FIG. 2

Fig. 3—Regulation characteristic of a separately-excited generator. At high voltages the drop in voltage with an increase in load is relatively small, but at a low voltage it becomes proportionately large.

Fig. 4—Typical speed-torque characteristics of a separately-excited adjustable-speed drive.

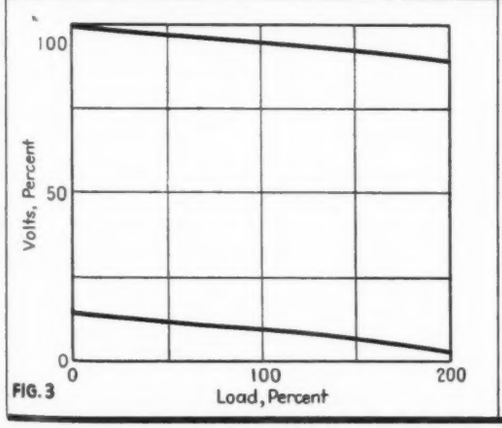


FIG. 3

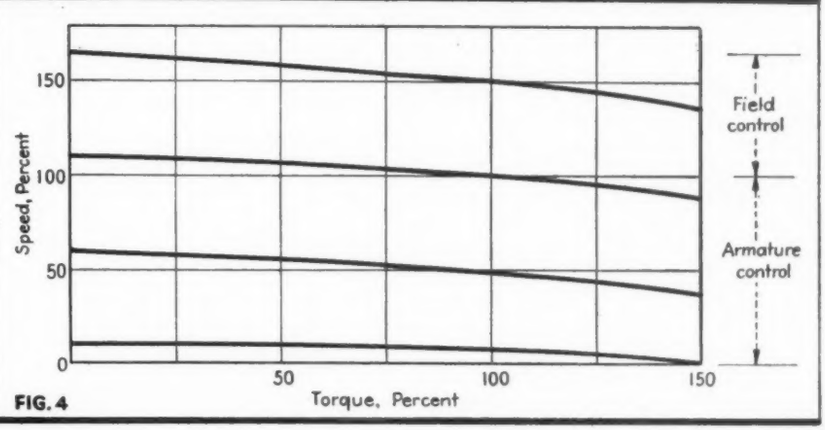


FIG. 4

of the motor, the current in the field of the generator is reduced causing the generator to supply a lower voltage to the armature of the motor. Since the *IR* drop for full-load current is just as much at high speed as at low speed, this voltage drop determines the lower limit that the speed of the motor can be decreased by weakening the field of the generator.

For example, with full-field excitation on the generator and full-load amperes flowing assume the *IR* voltage drop is five percent of the generator voltage. If the generator's excitation is reduced until the generator voltage is ten percent of the full-field voltage, the *IR* voltage drop instead of being five percent is 50 percent of the total generator voltage. This condition, shown in Fig. 3, gives poor speed regulation of the motor. A compound winding might be applied to maintain the generator voltage more nearly constant but it is difficult to make it equally effective at all speeds. In small sizes, if the cost is to be kept down, a speed range of about ten to one is about the most to expect from generator field control.

With separate excitation, the motor field strength can be decreased to increase the motor speed above the full armature voltage speed. This provides usually about a two to one speed range with standard motors, but can be as high as eight to one by using costly special motors. For a practical drive at reasonable cost, the combination of generator field and motor field control will give a maximum speed range of about fifteen to one, Fig. 4. Throughout the armature voltage controlled speed range ,the motor rating is on a constant torque basis. When the

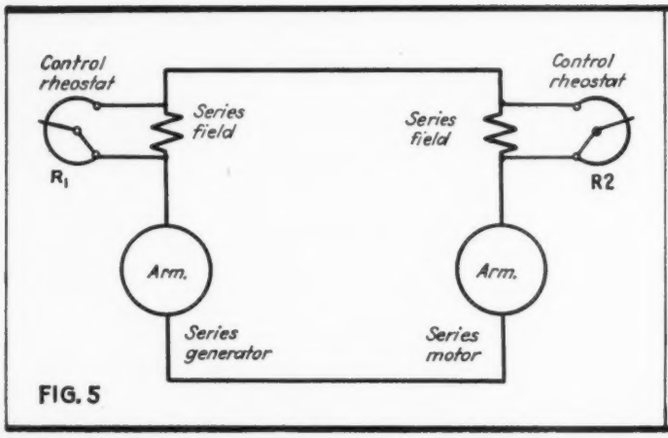


FIG. 5

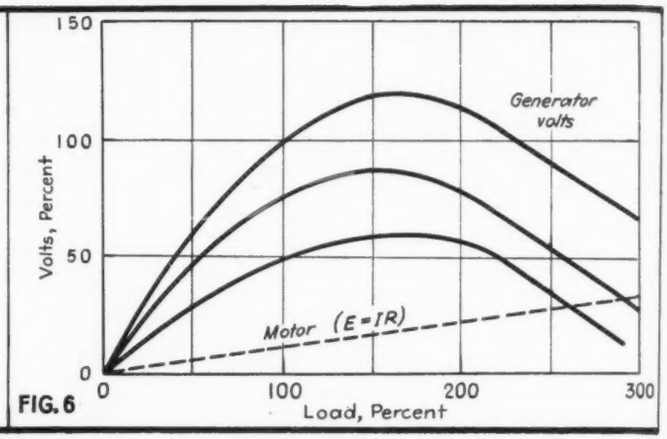


FIG. 6

Fig. 5—The series variable-voltage drive furnishes its own excitation. For any given load, reducing the resistance R_1 decreases the generator voltage and reduces the motor speed; reducing R_2 weakens the motor field and increases the motor speed. Fig. 6—Regulation characteristic of a series generator. With the field amperes partially shunted out by the rheostat, the slope of the characteristic curve is changed. After saturation the voltage falls off. The starting characteristic is represented by how much the generator curve is above the linear motor curve.

motor field is weakened, the load capacity is on a constant horsepower basis, which means that the torque must decrease as the speed is increased.

Adjustable-voltage control, with separate excitation, is often used for motors with ratings from one horsepower on up. However in small sizes, the exciter and necessary control are a substantial portion of the total cost of the drive. To reduce the cost of small units, the control has been simplified and exciter eliminated by means of self-excited drives such as the series system.

Self-Excited Series Drive

The series adjustable-voltage drive, Fig. 5, is probably the simplest adjustable-speed drive for low power yet developed. Basically it consists of a drive motor, a series generator, a series motor, and two rheostats.

A series generator will excite itself provided: (1) There is some residual magnetism, (2) the field is connected in proper relation to the armature, and (3) the connected load has not too high a resistance. Where:

E_g = generator voltage
K = constant
I_g = generator amperes

it can be shown that up to the saturation point, the voltage will increase as the amperes are increased, or approximately:

$$E_g = KI_g \qquad (1)$$

A series motor operated from a constant-voltage source tends to run away at light loads, the speed dropping rapidly as the load is increased. Where:

S_m = speed of motor
K' = constant
e = voltage
I_m = motor amperes

the speed of the motor is:

$$S_m = \frac{K'e}{I_m} \qquad (2)$$

Since both machines are in series, Equation (1) can be substitute for e in Equation (2), obtaining:

$$S_m = \frac{K'(KI)}{I} = K'K = \text{a constant}$$

Therefore, a series motor when supplied with power from a series generator will run at a substantially constant speed although the load varies. As shown in Fig. 6, the speed is adjusted by changing the field characteristic of the generator (constant K) and the field characteristic of the motor (constant K').

The power output of the series generator varies as the square of the amperes and this reduces the heating of both the motor and the generator for intermittent overloads. Also, for lower speeds the field losses are no more than for the high speeds. Since there are no field losses when the machines are disconnected, this also reduces the heating on intermittent loads.

The series drive has some advantages for fractional horsepower adjustable-speed applications. A speed range of fifteen or twenty to one is possible on a constant-torque constant-horsepower basis, as shown by Fig. 7. The cost of an exciter is saved, and this is a high percentage of the cost in any fractional horsepower drive. Control is easily applied to the series drive. Reversing is obtained across the line by reversing the motor field, and dynamic braking of a reversing drive is not difficult. Relatively new, the series drive has been in use for only five years but is being increasingly applied as its performance characteristics are becoming better known.

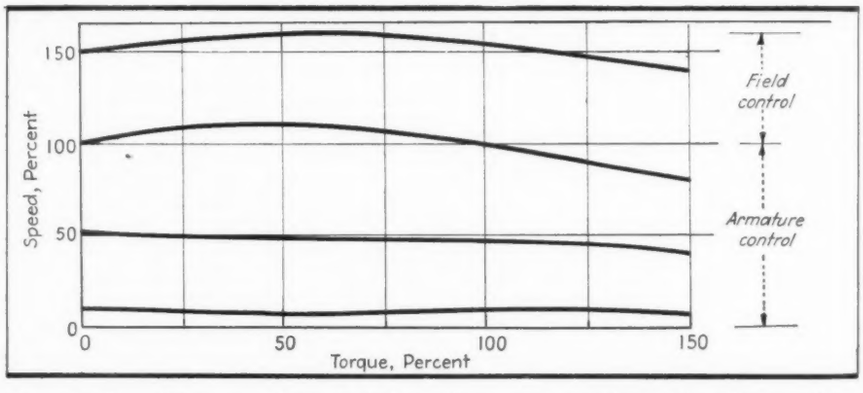


Fig. 7—Speed-torque characteristics of a series adjustable-voltage drive.

Compound Excited

Since with increasing load the separately-excited generator has a drooping voltage characteristic and the self-excited generator has a rising voltage curve, compound-excited generators combine the two. This usually provides a flat or slightly rising voltage characteristic. Such a drive combines good features of the other two except that the magnetic characteristic of the generator makes it difficult to compensate for the causes of poor speed regulation at all speeds.

If the drive is separately excited, the series winding of the generator is not very effective at high generator voltages due to the saturated condition of the generator field. However, at low speeds, the generator

field strength is low and a strong series winding becomes quite effective. This type of drive performs like the separately-excited drive at high speeds and the self-excited series drive at low speeds and is generally able to carry heavier overloads at the low speeds than the separately-excited drive and has better commutation under starting and reversing conditions. A typical circuit, and regulation and performance characteristics are shown in Figs. 8, 9, and 10, respectively.

Compound self-excited units have been tried for special applications. These are essentially series machines with auxiliary shunt fields. The generator shunt field must have a high resistance so that the generator cannot excite itself through this field alone, otherwise the adjustable speed features may be lost. The motor shunt field may be of a lower resistance to permit self-excitation should the load be overhauling and the motor driven as a generator, a condition that cannot be obtained with a straight series self-excited drive.

For fractional horsepower drives, compound machines are probably more complicated than is justified except in cases where unusual performance characteristics are required. However, most special requirements can be met by the selection of a suitable compound drive.

Relative Control Considerations

Control considerations are often an important factor in selecting the best adjustable-speed drive for a given service. The self-excited series generator must be designed to have some residual magnetism at no-load, usually of the order of three to five percent of the no-load saturation. When the generator is connected to a motor it takes a little time for the voltage to build up, so fractional horsepower series motors can be thrown directly across the line even on jogging service.

Separately-excited drives can also be thrown across the line by having the generator field circuit open, and closing the generator field at the same time the armature circuit is closed. Dynamic braking is easily obtained on separately-excited drive motors, but a series motor will not build up a voltage as a generator unless the field connections are reversed. For dynamic braking, a two pole double throw switch, or its equivalent, reserves the field of the series motor.

Table I — Relative Characteristics of Three Types of Drives

	Separately Excited	Self-Excited	Compound Excited
Regulation	Fair	Fair	Good
Starting torque	Fair	Good	Fair
Speed range:			
Armature	Good	Good	Fair
Field	Good	Good	Fair
Reversing service	Fair	Good	Good
Braking:			
Dynamic	Good	Fair	Fair
Regenerative	Good	Poor	Fair
Heating on Intermittent duty	Fair	Good	Good
Simplicity	Fair	Good	Fair

The inductance of a series motor and generator is high and this tends to cause arcing and possible welding of the contacts of the controller. So, care must be taken in applying a control and it may be necessary to connect several contacts in series to handle this inductance. However, the series machines commutate well and will stand frequent jogging and braking without sparking of the brushes or excessive wear of the commutator. With separately-excited drives, it is sometimes necessary to use some current-limiting means for starting motors to prevent sparking at the brushes.

Compound-excited drives might simplify an otherwise complex control problem and should certainly be considered where the control is difficult or proportionately high in cost. Under certain conditions, a pulsating or reversing drive is possible without additional control equipment. For the most part, these are electrical curiosities, but they may be put to practical use some day.

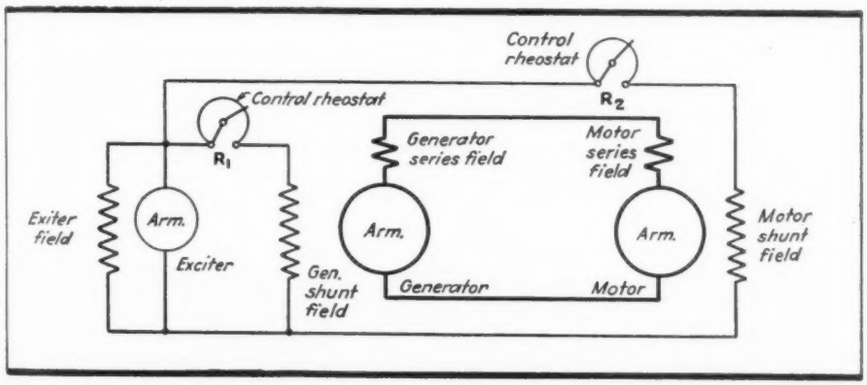
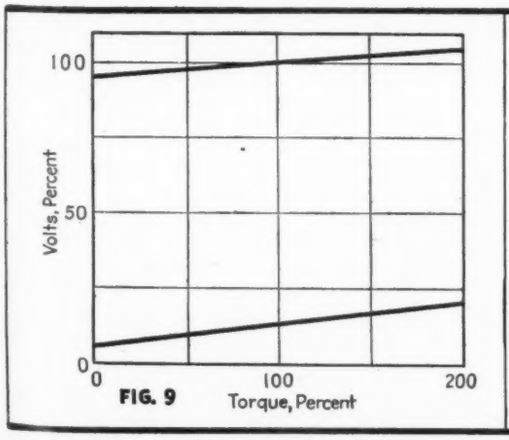


Fig. 8—Circuit diagram shows a combination of circuits shown in Figs. 2 and 5. Excitation is primarily from the exciter at light loads, but the self-excited component is predominant at heavy loads.



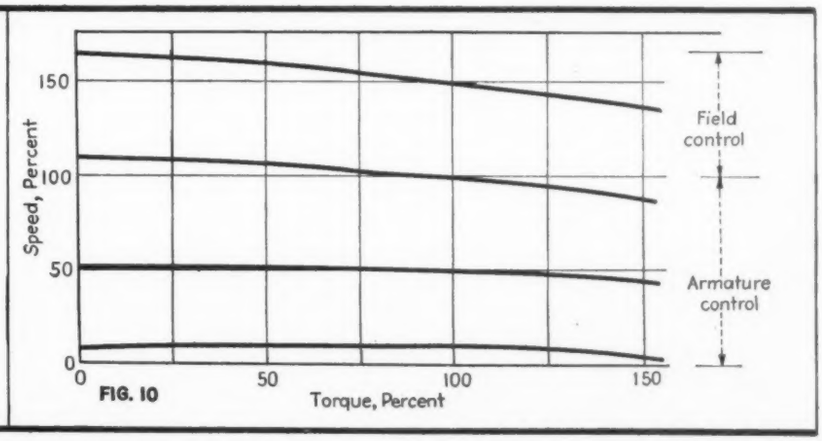
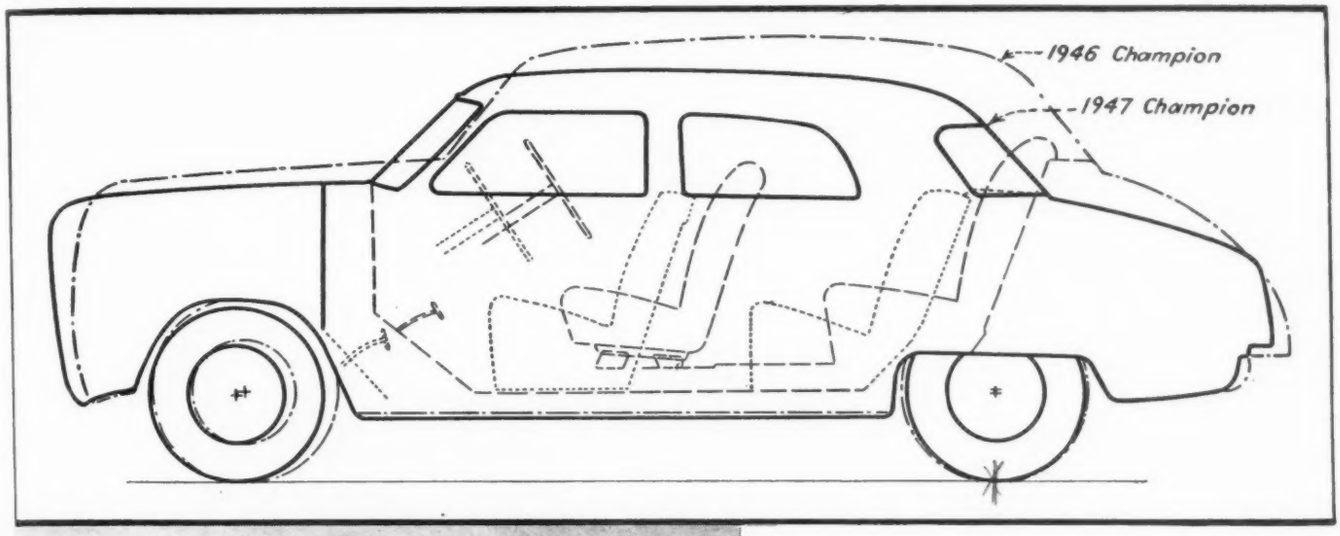


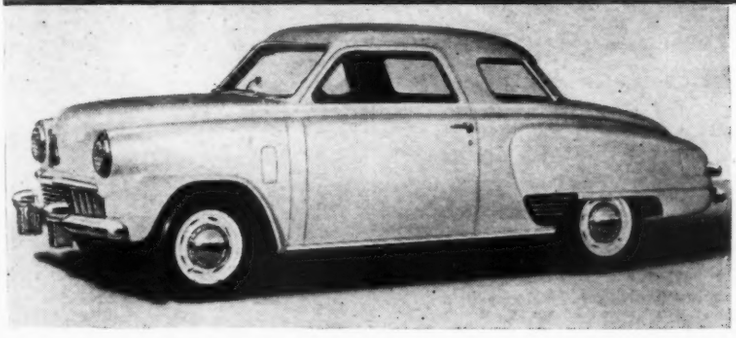
Fig. 9—Regulation characteristic of a separately-excited generator with cumulative compounding. The rising voltage characteristic is designed to compensate the line drop and the increased *IR* drop in the motor at heavy loads. The compounding is more effective at the lower voltages so that it does not entirly provide correct compensation except over a narrow speed range. Fig. 10—Typical speed-torque characteristics of a combination drive.

PRODUCT DESIGNS

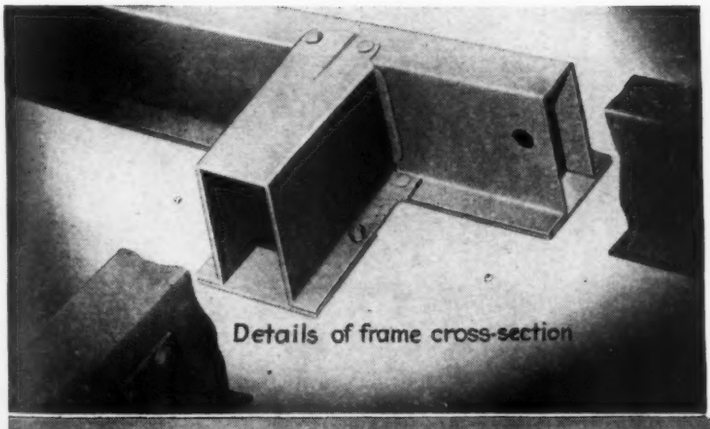
Design Features of the 1947 Studebakers

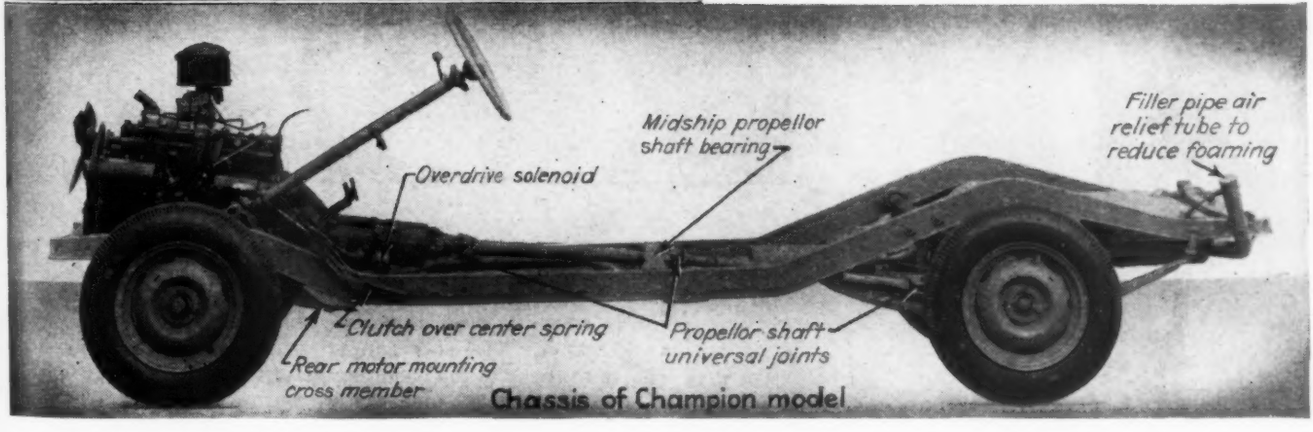
STUDEBAKER 1947 Champion and Commander models, styled by Raymond Loewy and designed by Studebaker engineers, present the first new postwar automobiles in production. Principal apparent style features are the greatly increased visibility, doubled in the 5-passenger coupe illustrated, a low body height of 60¾ in., a front seat width of 60 in., and a front fender line integral with the body line so that an effect of low, massive streamlines with few bulges and little chrome trim results. Greatly improved ride results from moving the 80 hp. Champion engine 9 in. forward, using front kickups to further lower the frame, using softer springs, with floating ends on front springs, and cradling both front and rear seats between the wheels. Self-adjusting brakes, a two-piece propeller shaft, a double-flanged box girder frame, both upper and lower control arms on the front suspension, a cable-operated windshield wiper with two vacuum sources, and black lighting for the instruments are the main new mechanical design features. Instrument figures are made with fluorescent paint. Bulbs in each instrument shine through glass filters which permit the passage of light rays of the ultra violet region of the spectrum. Filtered rays cause numerals of dials to glow with a subdued greenish luminosity, clear yet nonglaring. Button switches on all doors operate map and body lights. When the hood is raised, the engine compartment is illuminated. A mercury switch is used to complete this circuit. Trunk and glove compartment are similarly lighted.



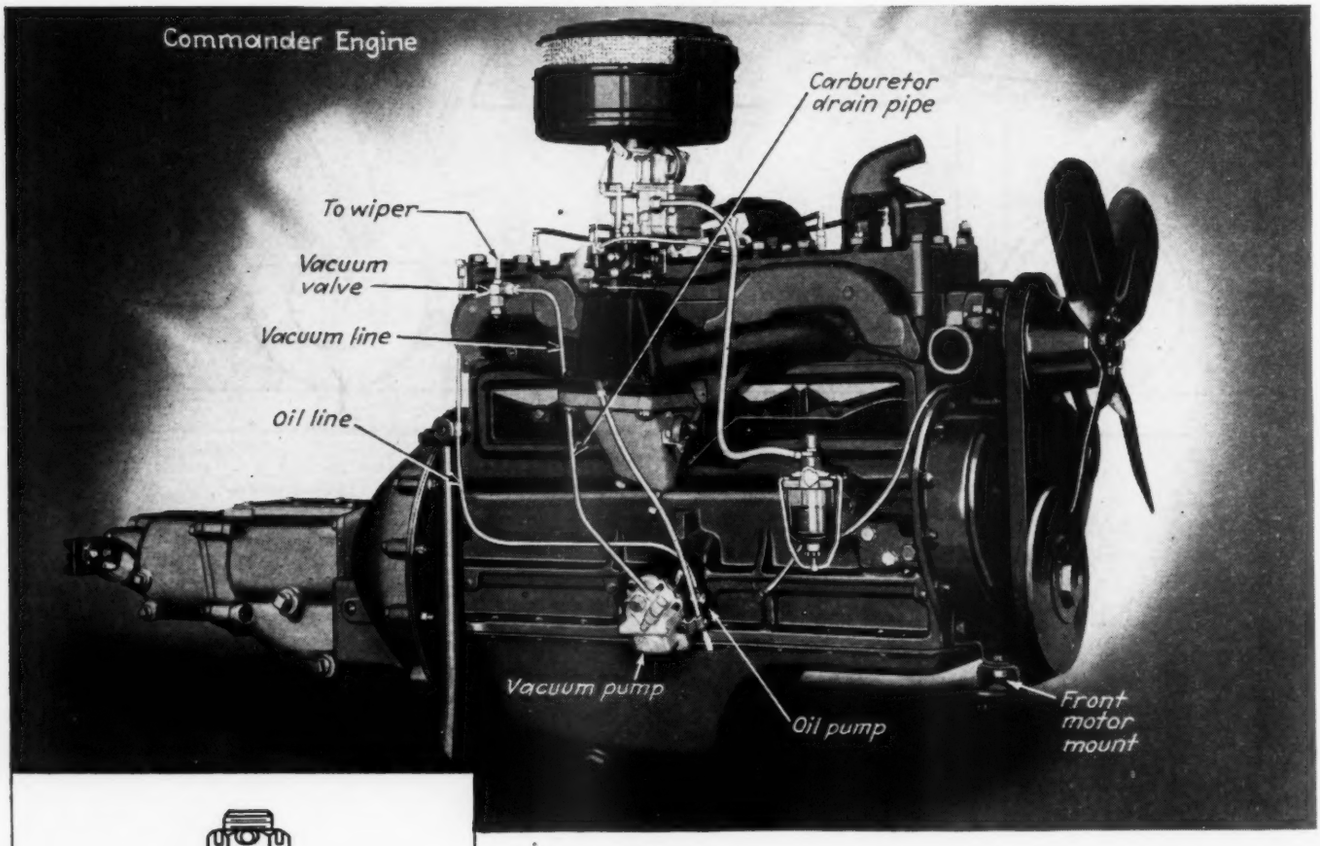


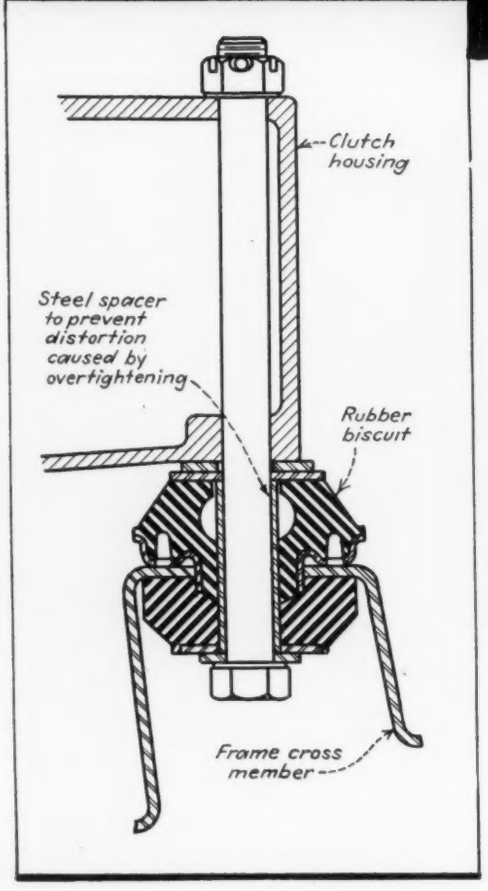
Front kickup on frame and 10¼ inch rear kickup result in lower mounting of the passenger compartment. To increase passenger space and put the compartment well forward, the engine has been placed in an extreme forward position. Engine is mounted so that axis of crankshaft and forward section of propeller shaft approach a straight line to minimize universal joint wear. Two-piece propeller shaft reduces whip and avoids need of a rear floor tunnel. Midship propeller shaft bearing is press fitted into a rubber mounted housing on the mid-frame cross member. Box type, double flanged frame section, 4⅛ inches deep, is strong and body mounting lugs are fastened to flanges so that door sill is flush with top of frame section. Rear motor mounting cross member extends beyond frame to support the wide body at front of passenger compartment. Brake and clutch pedals straddle the frame and are both lubricated through one fitting. Clutch lever has over-center spring to reduce pedal effort required.

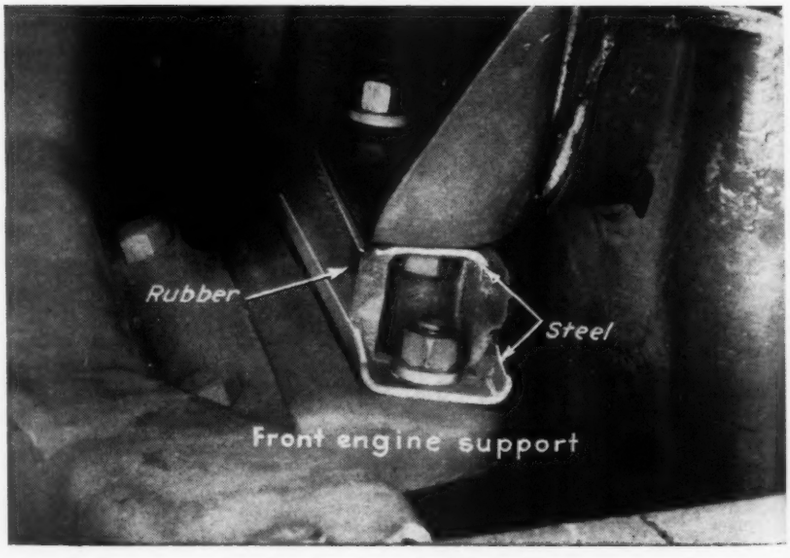

Details of frame cross-section


Midship propellor shaft bearing
Filler pipe air relief tube to reduce foaming
Overdrive solenoid
Clutch over center spring
Rear motor mounting cross member
Propellor shaft universal joints
Chassis of Champion model

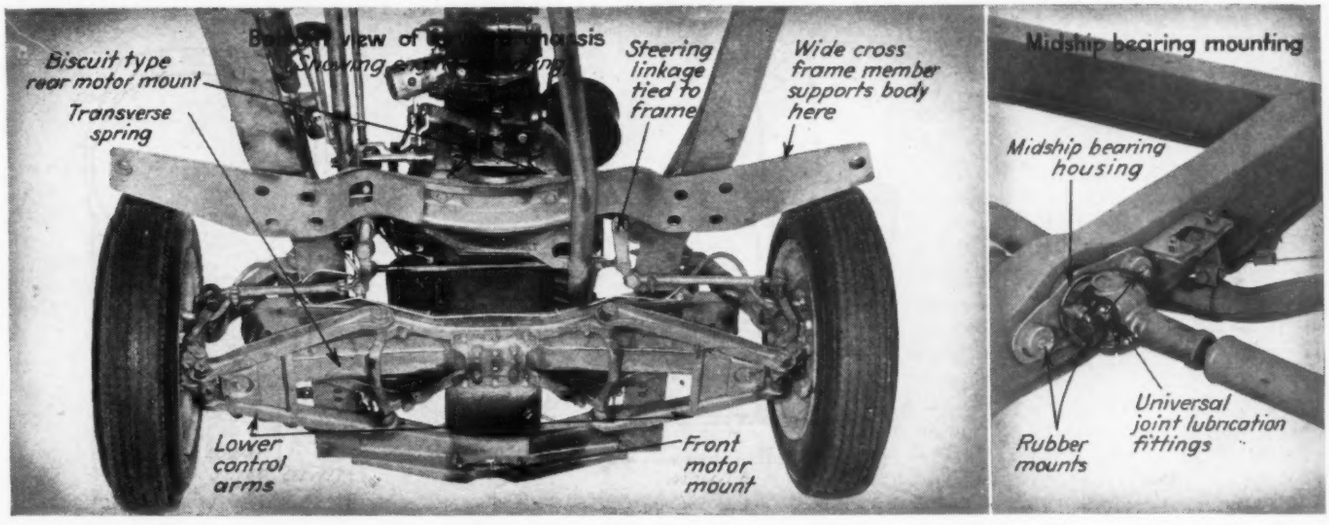
1947 Studebaker (continued)

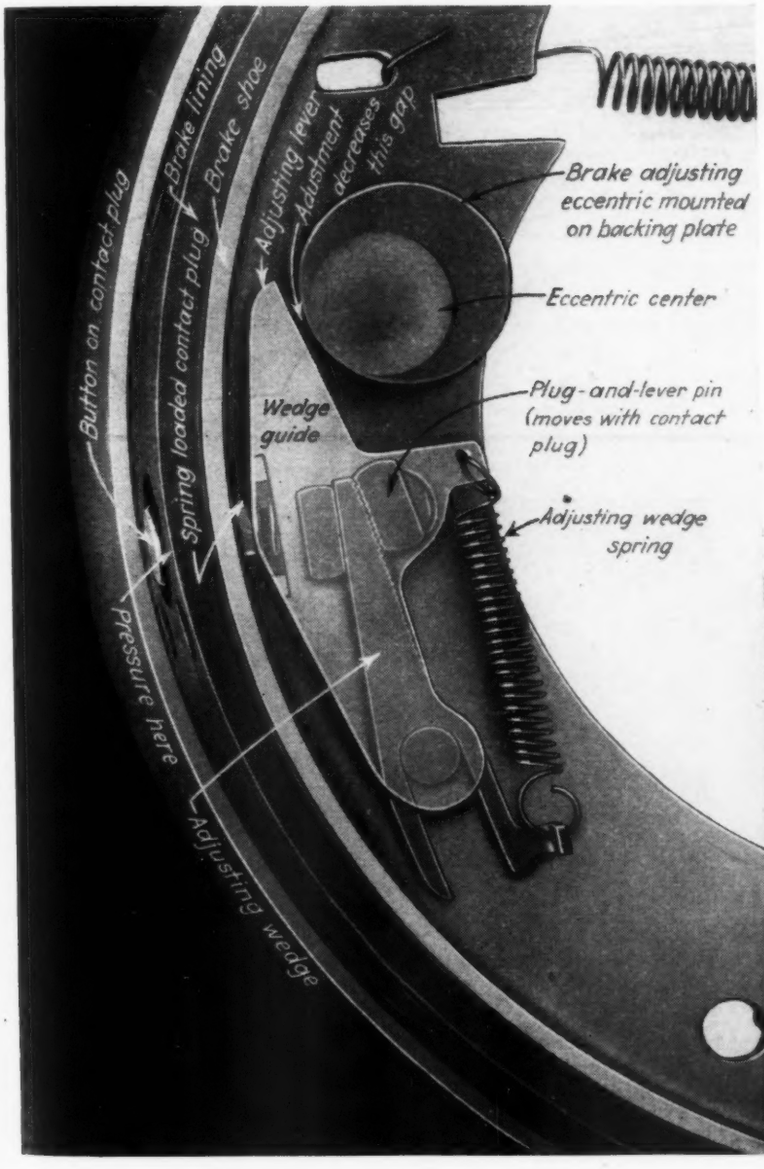




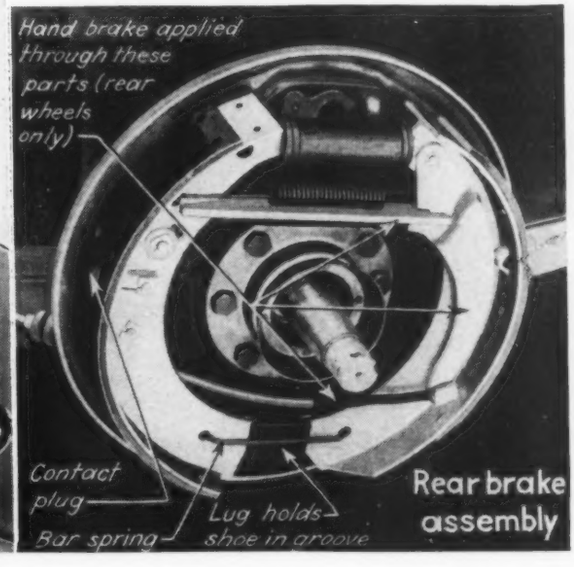


Oil pan has unusual design to clear the front suspension. Connecting rod bearing inserts are used. Top of intake manifold is milled at an angle so that the carburetor sits vertically. Engine is supported by three mounts. Forward mount is rubber of square cross-section bonded to steel mounting strips on top and bottom. Two rear mounts of the rubber biscuit type are fitted with spacers to regulate the compression of the rubber upon tightening of the mounting bolts.

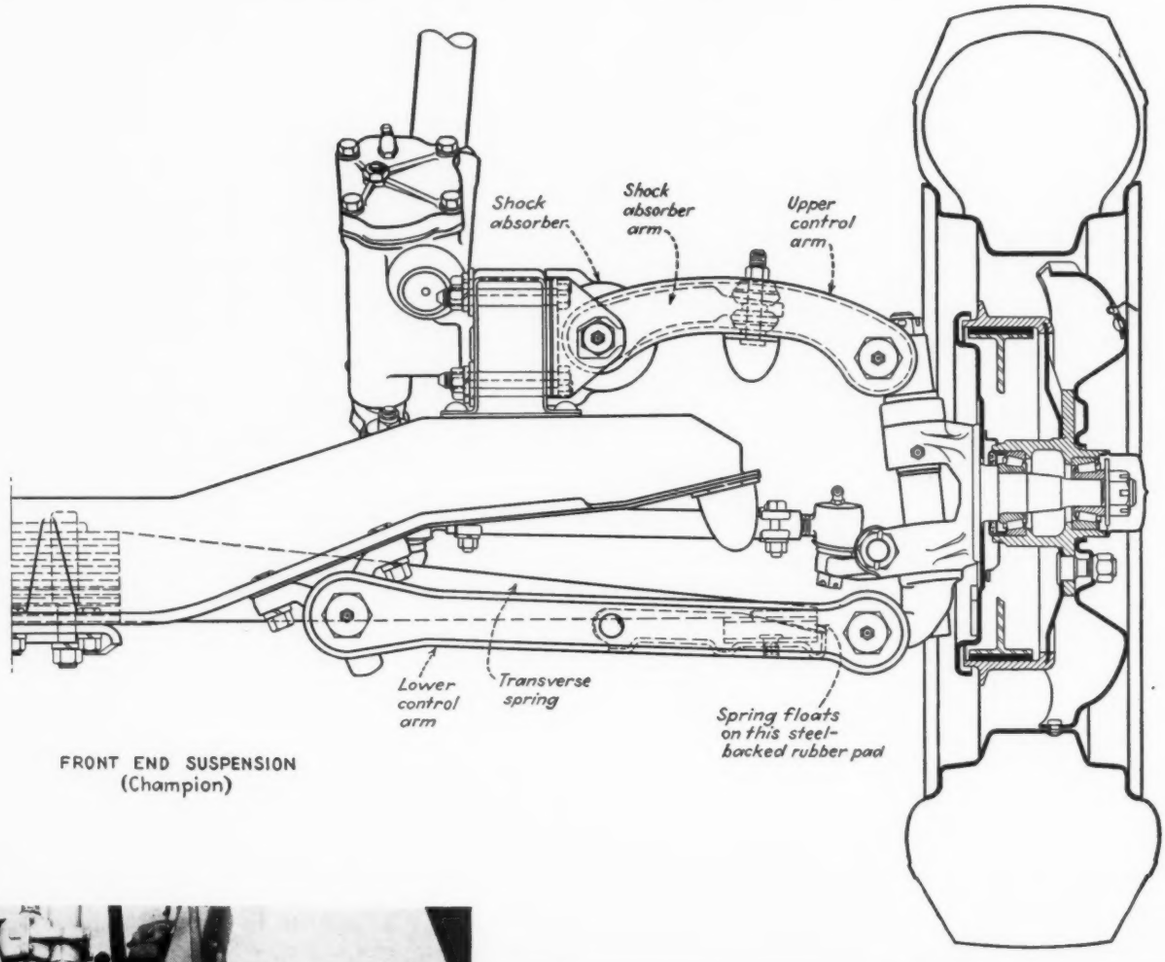




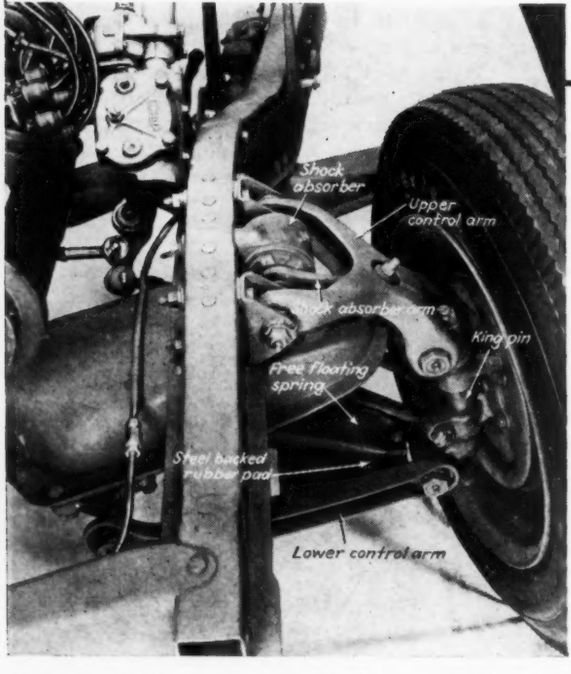
New brake design has self-adjusting front shoes on all wheels. Bottom ends of shoes are seated in a slot, held there by a bar spring, and are free to float vertically so that shoes are self centering. The self-adjustment device is based on the principle of increasing the depth of the brake shoe shoe rib where it rests against the eccentric. A spring-loaded contact plug, faced with bearing metal, projects through a hole in shoe and lining. When the lining wears sufficiently, the plug presses on the drum and is pushed to the rear carrying with it the plug-and-lever pin. This widens the opening between lever pin and wedge guide, and the adjusting wedge spring pulls the adjusting wedge upward until it notches in the next serration. Thus a slightly wider part of the adjusting lever is pushed against the eccentric and in effect results in a 0.005 in. adjustment of the lining. Rear shoes generally require no adjustment until front lining needs replacement.

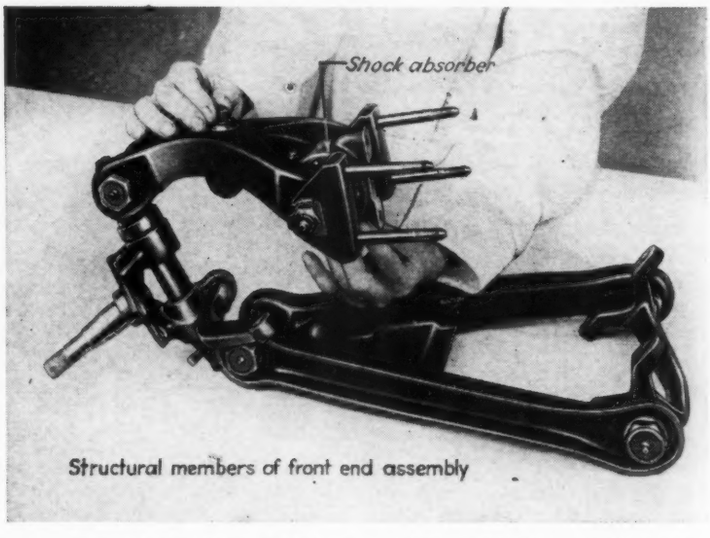

Hand brake applied through these parts (rear wheels only)
Contact plug
Bar spring
Lug holds shoe in groove
Rear brake assembly

1947 Studebaker (continued)



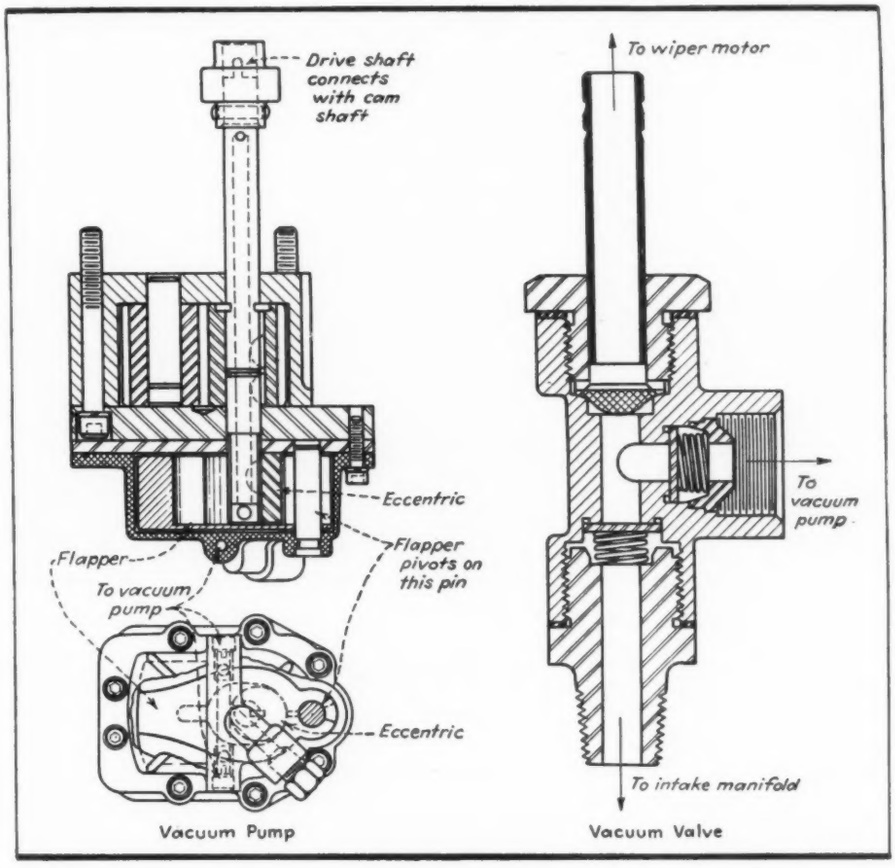
FRONT END SUSPENSION
(Champion)





Structural members of front end assembly

Each front wheel is independently sprung through upper and lower control arms. A single transverse spring supports the arms. Front spring is not a structural member as in previous models, therefore softer springs, imparting full resiliency to the suspension, are used. Lower control arms have been added to resist horizontal road shock. The ends of the transverse spring float on steel-backed rubber pads resting on the lower control arm. This makes for sturdier wheel alignment. Shock absorber is mounted in cutout of upper control arm.



Steadier wiper operation results from using two sources of vacuum for wiper motor. In addition to the usual vacuum from the intake manifold, a vacuum pump is built in over the oil pump in the commander models. Vacuum pump drive shaft, running off the oil pump shaft, rotates an eccentric that oscillates a flapper within a housing. Flapper covers and uncovers valve ports in cover plate. A vacuum check valve is mounted on the engine and is connected to both intake manifold and vacuum pump. Wiper motor thus operates from the stronger vacuum source. The windshield wiper uses a cable drive rather than the usual cam and lever type. Steel cables run over pulleys which have been mounted on large diameter ball bearing axles. Easy turning reduces slippage of the cable and the consequent wear at the point of contact between cable and pulley. Cable tension adjustment is quickly effected by loosening a single nut in the corner bracket. A strong coil spring then pushes the bracket outward and rearward to exert the proper degree of cable tension.

Random Notes on Reconversion

Light, "economy" cars by Ford and Chevrolet, the Studebaker models described in this issue, and possibly the Kaiser-Frazer products, appear to be the only new cars that will be built in 1947. Company officials who are willing to discuss their cars say that brand-new automobiles will not appear until 1948. Principal engineering changes will include improved brakes and suspensions. Automatic transmissions can be expected in most cars, and plastic fabrics will probably replace less durable upholstery.

* * *

Aluminum furniture is being produced in large quantities by Eisen Bros. of Hoboken, N. J. Primary reason for the summer boom, even though costs are higher, is that the light weight and rust-proof qualities of aluminum make it ideal for outdoor use.

* * *

Phosphate coating for the entire 1946 line of Ford and Mercury cars has been announced by the Ford Motor Company. Process is a combination etch and surface chemical change since iron is replaced by the formation of metal phosphate. The resulting roughening is imperceptible to the touch but serves as an excellent paint bond.

* * *

Rubber tires in a color to match the paint job on your car are indicated by a development of the B. F. Goodrich Company, Akron, O. A newly discovered compound of powdery, fumed silica, with the paradoxial name of "white carbon-black" will replace the old carbon-black used to increase the tensile strength of certain synthetic rubbers. All kinds of colors can be given to rubber with this substance.

* * *

Mica shortage in Germany during the war lead the Robert Bosch Co. to develop a glass fabric impregnated fiber claimed to be superior to mica as an insulator between commutator segments. Glass fabric of thread thicknesses from 0.015 to 0.022 mm. dia. 15 to 21 threads per cm. and of an alkaline content of 6 to 9 percent is impregnated with a solution then baked at 120 deg. C. Solution (by weight) consists of 53.3 percent Resinol K-2 (not fully polymerized), 23.3 percent alcohol (CR), and 23.3 percent Osmose-Caoline. Three strips of fabric are then molded together under 350 kg. per sq. cm. pressure at 160 deg. C. for 5 min. Finished product is non-hygroscopic, does not change in weight or dimensions at 100 percent humidity and [illegible] deg. C, and can stand 250 deg. C, indefinitely. Any manufacturer set up to make phenol fiber could produce this material with minor investment in new equipment.

* * *

Coin-operated radio sets for hotel rooms are being built by the General Electric Company for Radiomatic of America, Inc. Production of 8,000 receivers per month is planned. Sets are about the size of large table top models. A quarter must be dropped in the insertion mechanism on the top to operate the set.

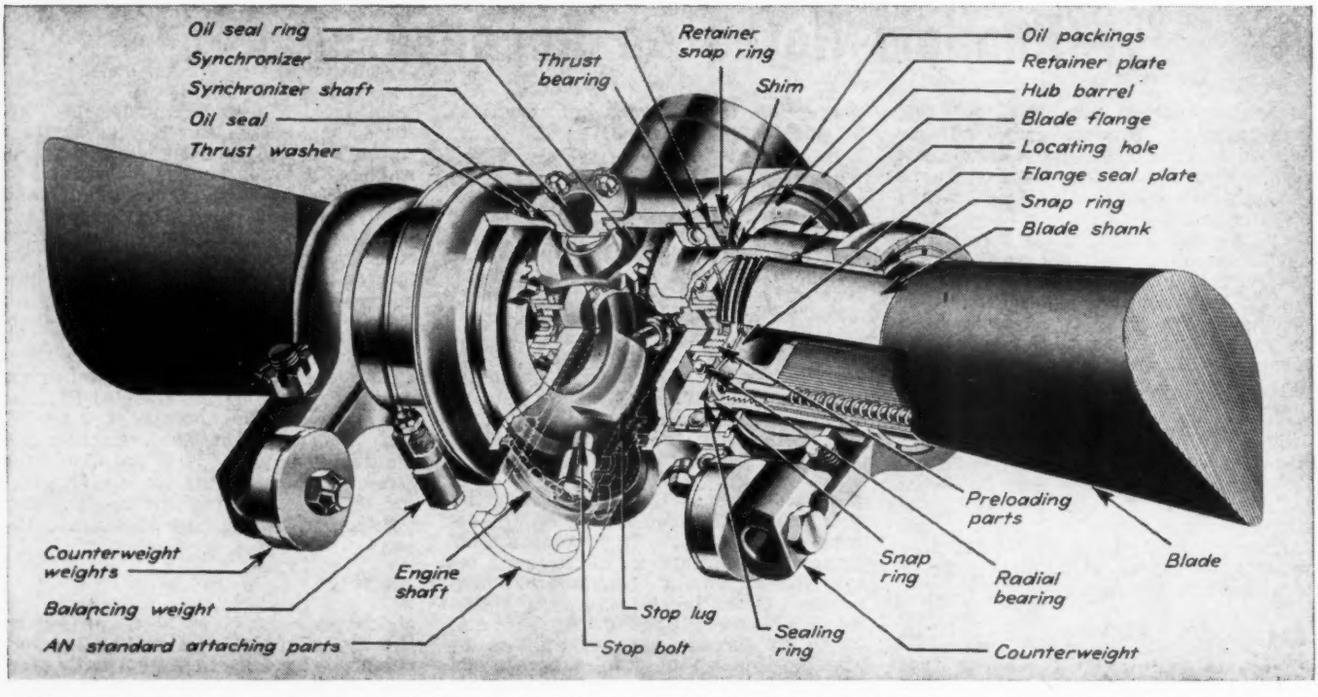
* * *

Nylon production has been speeded by the use of magnesium in knitting machinery. By replacing steel with magnesium for the needle bars, machine speeds have been increased. Substituting magnesium for ferrous materials in the bobbins, spools, and other components of textile machinery has cut down vibration and thread breakage.

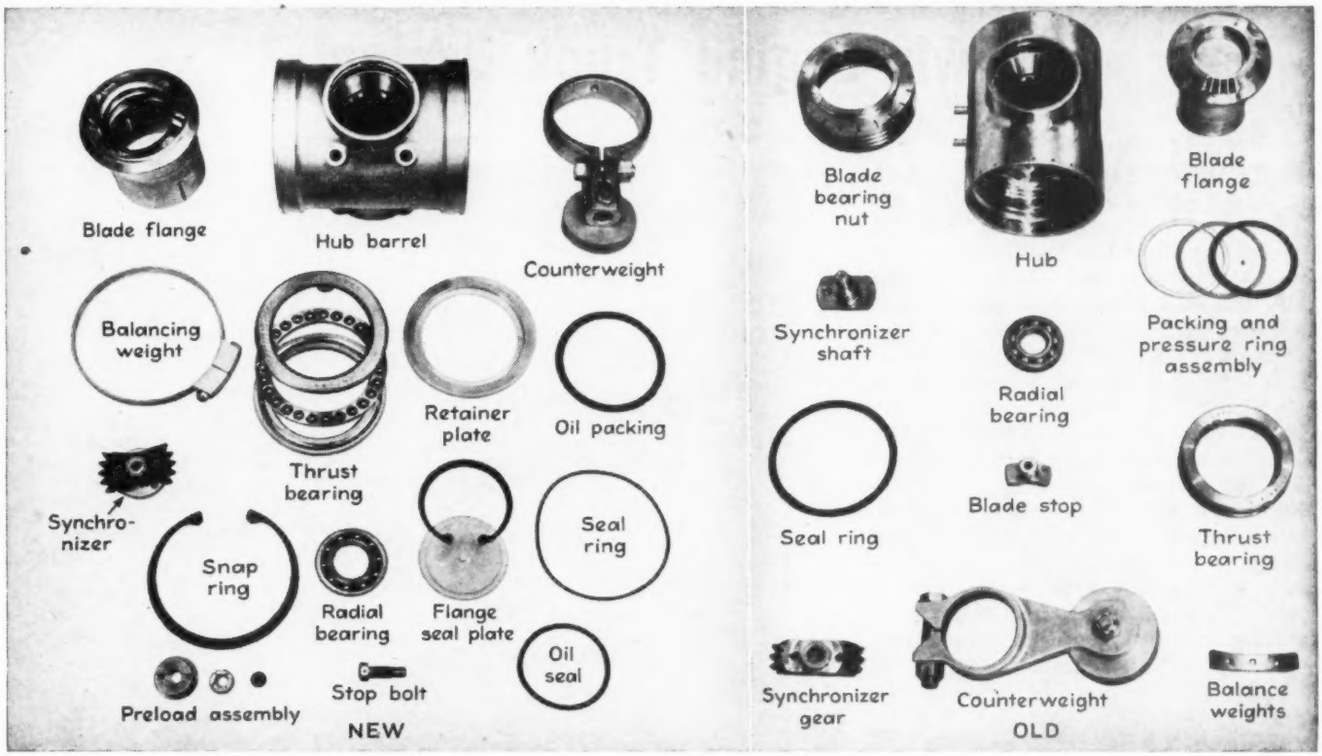
Redesign Reduces Cost And Improves Automatic Variable Pitch Aircraft Propeller

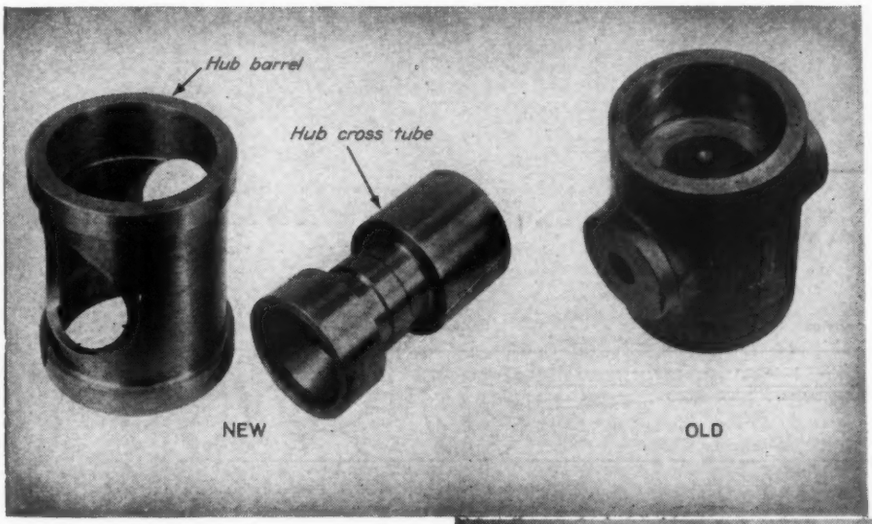
Robert Yarnell Ritchie

AIRCRAFT PROPELLER of the full-automatic variable-pitch type requires no cockpit controls or modification of the aircraft or engine. Manufactured by Koppers Company, Inc., Bartlett Hayward Division, under patents of the Everel Propeller Corp., the propeller is designed for light and medium aircraft and is known as the Aeromatic Model 220 propeller. Parts have been redesigned to assist maintenance and disassembly. Performance has been improved and weight and cost reduced. Pitch change is obtained entirely from the action of physical forces of thrust acting on the blades and centrifugal force acting on the counterweights. The counterweights are positioned close to the hub and allow a clean spinner design.



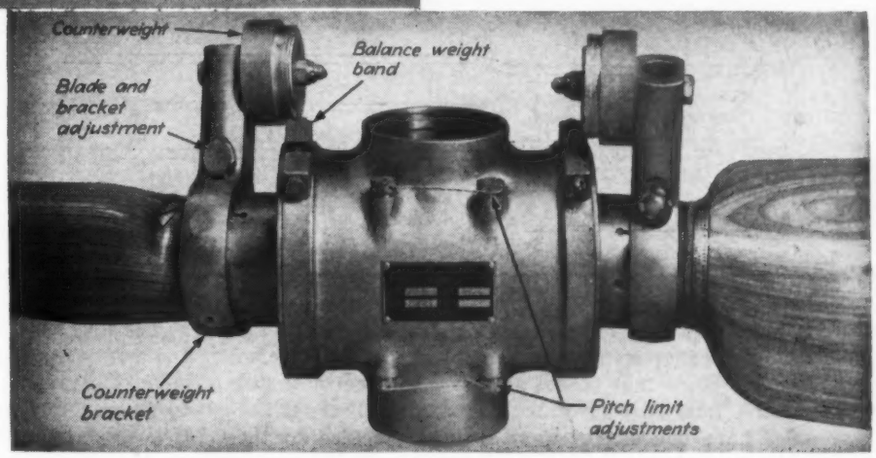
Redesigned propeller has hub with thinner walls. Hub parts are held in place by retaining snap rings. Counterweight brackets and balance weights are of new design. Blades are retained by threads located on the inner end of the blade shank ferrule and are removed by loosening the counterweight clamping bolt. Thus, when clamping pressure on the ferrule is released, the blade can be unscrewed for replacement to facilitate hub disassembly.





Hub assembly was completely redesigned. Threaded inner lip on original hub design has been replaced by a ring groove for a retaining snap ring. Balance weights originally held to the hub rim by screws through the blade locking nut have been replaced by a strap fitted to the rims of the hub. Counterweights were redesigned for better accessibility of the clamp bolts and reduced machining.

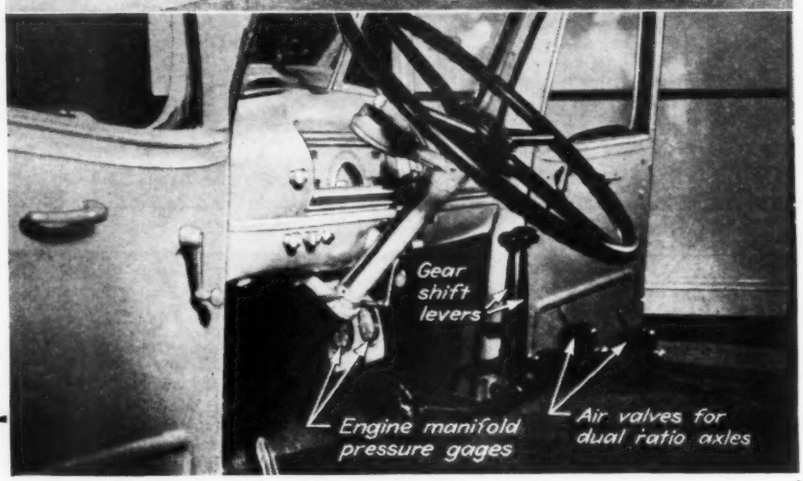
Hub was originally a solid alloy steel forging. As redesigned, it consists of two pieces, the hub barrel and cross tube, both made from seamless alloy steel tubing. The two pieces are joined by atomic-hydrogen welding.



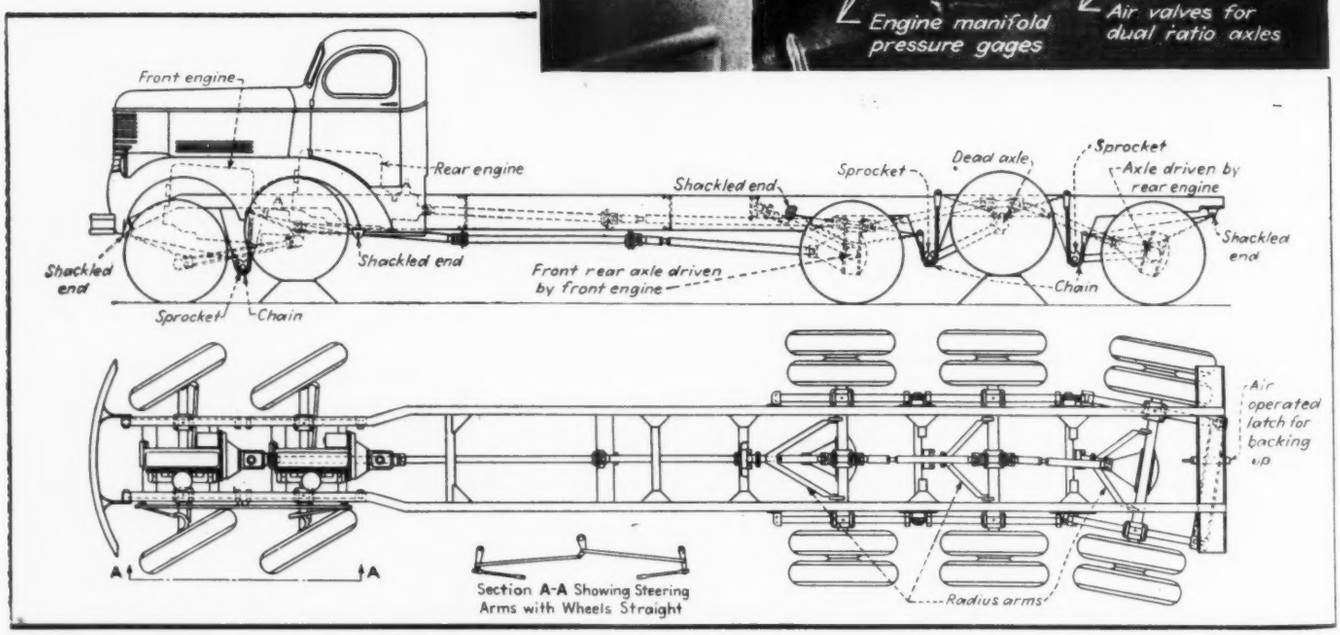
Redesign has made all adjustments accessible. Pitch limit adjustment, counterweight adjustment, vertical and horizontal balance and lubrication fittings have been brought outside the hub.

Twin-Engine Truck Design

TRUCK DESIGNED for long distance hauling, with a payload capacity of approximately 20 tons, has been developed by the Truck Division of The Eisenhower Manufacturing Company. Use of four front wheels in tandem rather than dual relation eliminates the need for power steering. Two engines each drive separate rear axles and a third rear axle is "dead." Frame is rigid and a flexible type of suspension allows the frame to remain level. Overall length of the truck is 35 ft., with a truck bed of 25 ft. One engine is located under the hood and the other beneath the cab. Single radiator cools both engines through an interconnected cooling system. Engines can be used together or independently and when used together are balanced by a torque equalizer actuated by manifold pressure. Either motor can drive the single fan and compressor through a countershaft having an over-running clutch.



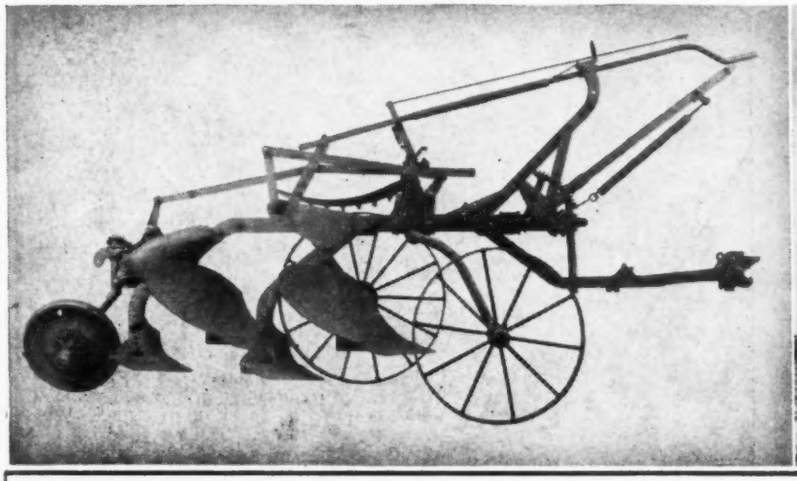
Gear shift levers are located directly under the steering wheel and can be shifted individually or simultaneously. Air valves control the shifting of the dual ratio axles. There are separate instruments for each engine but clutch and accelerator pedals are common to both engines.

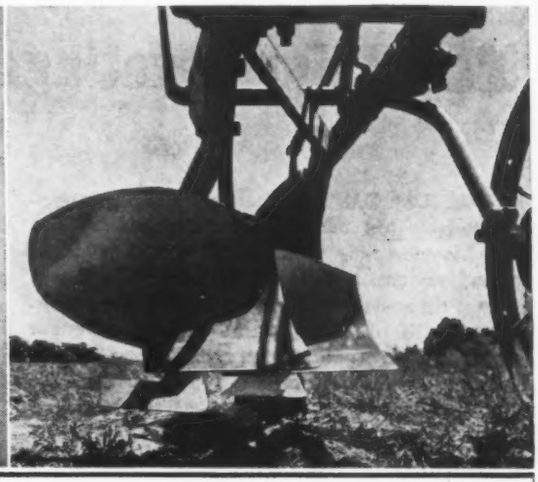


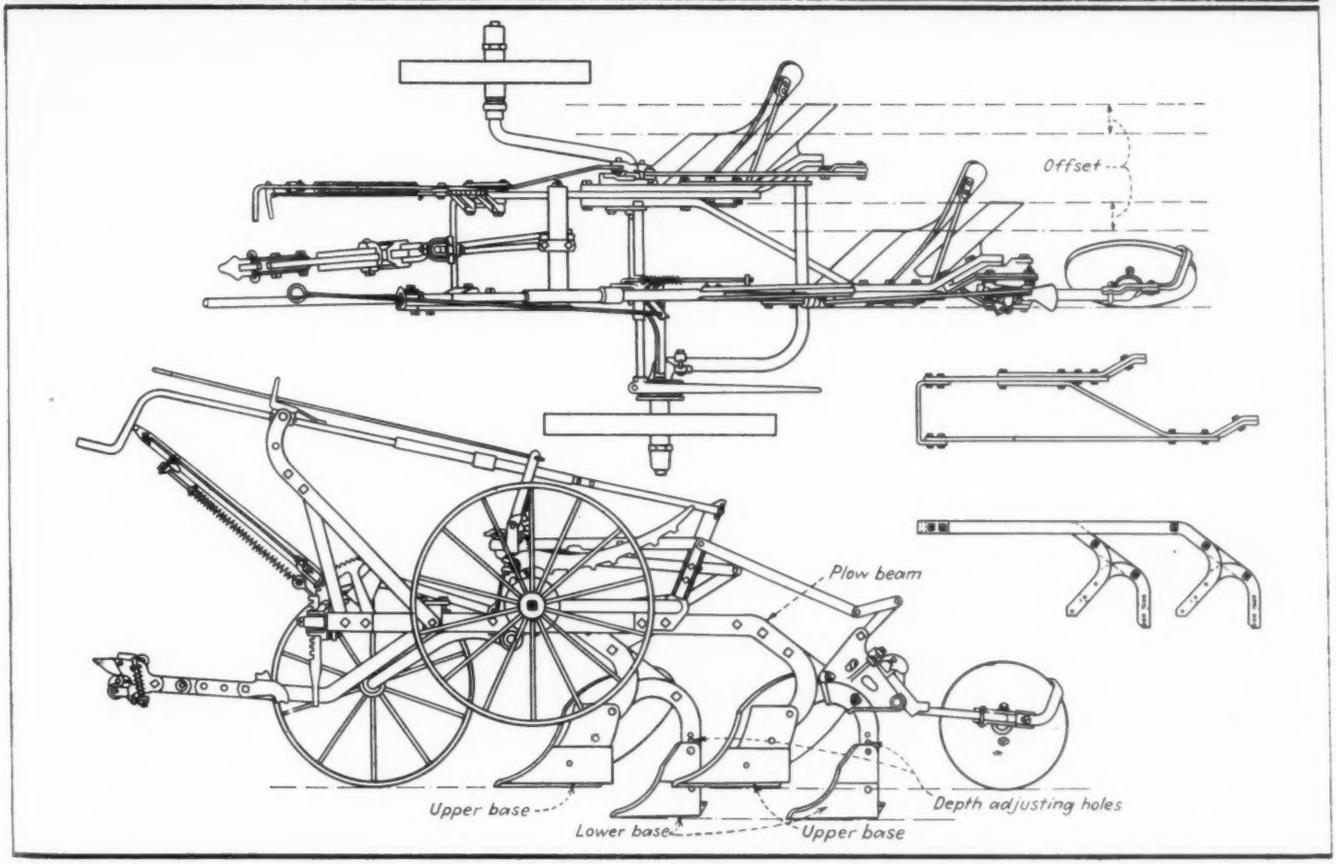
Front suspension consists of two axles each supported by leaf springs. One end of each spring is shackled to the frame. Other end of front and rear springs are connected together by a chain that passes around a sprocket attached to the frame. Rear suspension is similar but only front and rear axles have one end of their springs shackled to the frame. Both ends of center axle spring are connected through chains and sprockets to the unshackled ends of the front and rear axle springs. Radius arms control vertical movement of all rear axles and rear-most axle can shift laterally to follow the steering wheels on turns. This axle is latched in position by an air latch when the truck is backed.

Deep-Tilling Plow Has Two Bases

PLOW has been designed to break up the furrow floor, built up by conventional plowing, that results when the fine colloidal silt sifts down through the upper soil and forms a strata of gelatinous substance on the furrow floor. Developed by the Oliver Corporation the new plow, known as the Oliver TNT Plow, was designed by R. J. Altgelt. Plow has two bases. The upper bases are set at ordinary plowing depth while the lower bases are below and behind the upper bases and work slightly to one side. Since lower bases do not follow directly behind the upper bases, but are offset 4 in. away from the landslides of the upper bases, tractors now in use can readily pull this plow. Soil so tilled is claimed to be enriched by the mixing action.

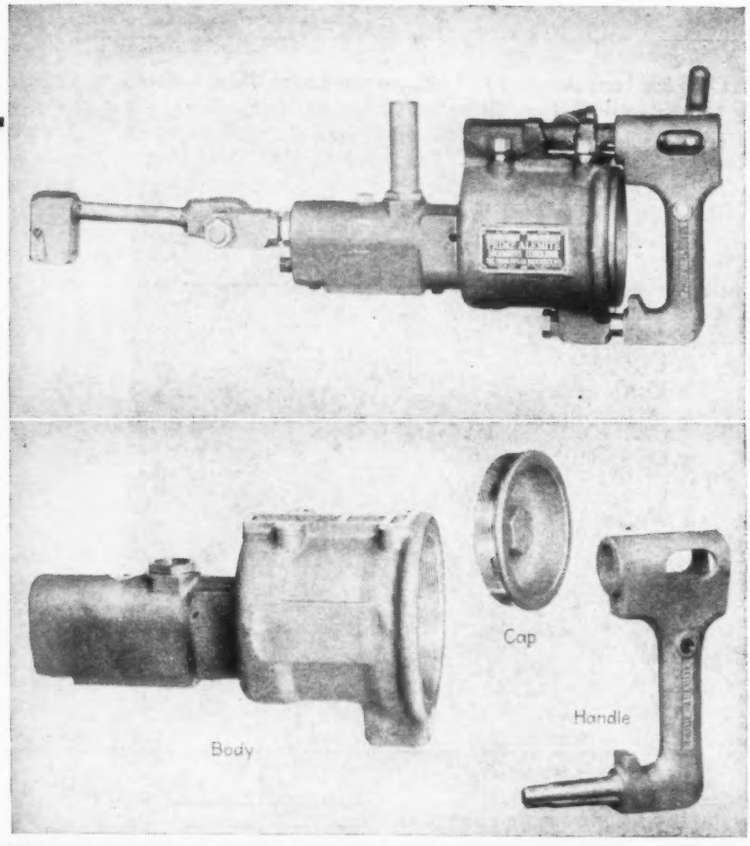




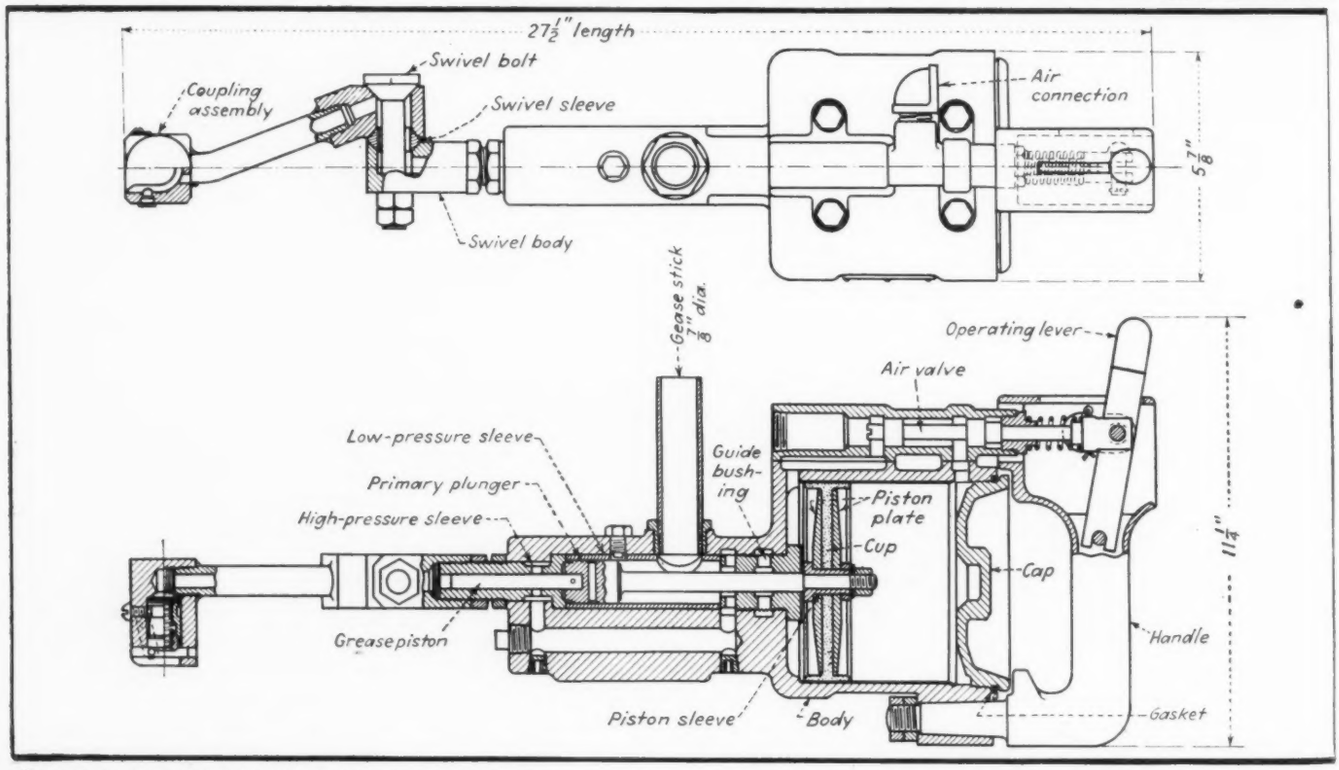


Plow beams are constructed from formed steel parts. Assembly is fastened by bolts for easy replacement or repair. Lower base is different from conventional subsoil attachments for plows. Conventional designs consist of points or narrow shovels. Holes in the plow beam permit the lower bases to be set 2, 3 or 4 in. below the upper bases.

High-Pressure Locomotive Lubricator Uses Magnesium Castings



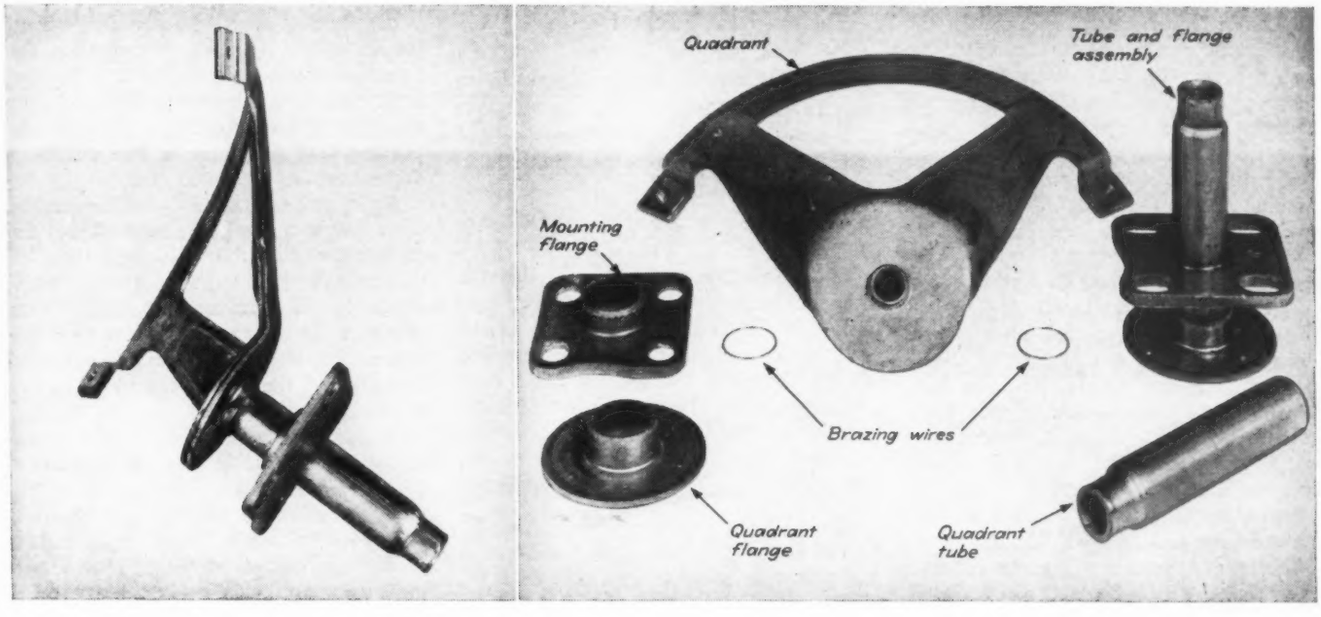
MAGNESIUM CASTINGS are used in an air-operated portable rod lubricator manufactured by The Prime Manufacturing Company. Designed to handle hard rod cup grease under all conditions, it is known as the Prime-Alemite Locomotive Rod Lubricator. Air pressure of 100 lb. per sq. in. develops a pressure of 17,000 lb. per sq. in. on the grease at the bearing. Total weight of the lubricator is 22 1/2 lb. Compact design and lightweight permit use of the lubricator without moving the locomotive. Body, cap and handle are magnesium castings having a total weight of 8 lb.



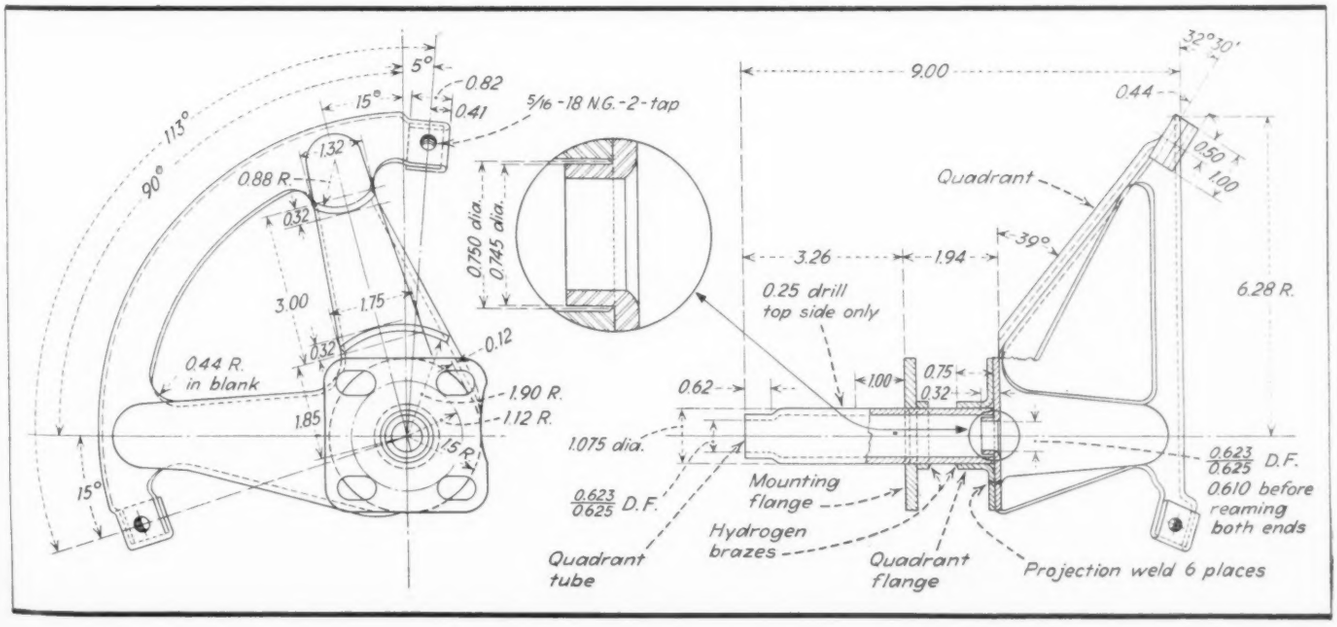
Grease is inserted into the lubricator in stick form, and is brought to the 17,000 lb. per sq. in. pressure in two stages. Air cylinder is of 5 in. diameter and consists of a molded packing held between two plates. Coupling assembly can be swiveled to assist in reaching fittings having close clearances. Fittings are chrome plated for longer life.

Hydraulic Lift Control Quadrant Made of Stamped Parts

QUADRANT DESIGNED to operate as part of a tractor hydraulic lift control is made of four stampings that are assembled by hydrogen brazing and resistance welding. As manufactured by the National Stamping Company, all parts of the quadrant are made from hot-rolled, low-carbon, open-hearth steel. Assembled quadrant requires only four machine operations; the tapping of two holes, drilling of one hole and a reaming of both ends of the tube. Lower cost and increased strength result.



Flanges are hydrogen-brazed to the quadrant tube. Quadrant is projection-welded to the quadrant flange in nine places after the flange is brazed to the quadrant tube.



Isolation of Vibration In Spring Mounted Apparatus—I

J. N. MACDUFF
General Electric Company

Simple classical theory of vibration is reviewed for a system having one degree of freedom with no damping, energy equations are derived. Procedure is then described for calculating linear and angular displacements, natural frequencies, and rocking and torsional modes of apparatus supported symmetrically on bottom mounts.

IN DESIGN procedures dealing with the isolation and prevention of vibrations in industrial equipment, the problem of properly mounting the apparatus is often inadequately studied. There is a general tendency to assume that a spring mounted machine will have only a vertical natural frequency. Since a mounted object will usually have at least six natural frequencies, such a procedure solves only one-sixth of the problem and may be embarrassing and dangerous.

The simple classical theory of vibration isolation is usually developed from an analysis of a mass-spring system like that shown in Fig. 1. In this system, the mass is so constrained that it can vibrate only vertically, it is a "single degree of freedom system." It has only one natural frequency, since the number of natural frequencies of a system is equal to the number of "degrees of freedom."

The natural frequency f_n, cycles per sec., of the system shown in Fig. 1 can be found from energy considerations. If the mass is pulled down and then released it will oscillate at its natural frequency.

Where:

- x = displacement of mass at any instant in.
- x_o = maximum amplitude or one half total travel of the mass, in.
- ω_n = natural frequency of the system, radians per sec.
- $f_n = \omega_n/2\pi$ = natural frequency of the system, cycles per sec.
- t = time, sec.
- v = velocity of mass at displacement x, in. per sec.
- K = dynamic spring constant, lb. per in.
- W = weight of mass, lb.
- $m = W/g = W/386$, lb. sec.^{2} per in.
- E_p = maximum potential energy in system, in. lb.
- E_k = maximum kinetic energy in system, in. lb.

the displacement of the mass is

$$x = x_o \sin \omega_n t \quad (1)$$

the velocity of the mass is

$$v = dx/dt = x_o\omega_n \cos \omega_n t \quad (2)$$

If damping is neglected, no energy will either enter or leave the system, and hence the maximum kinetic energy must equal the maximum potential energy.

The maximum potential energy E_p is

$$E_p = Kx_o^2/2 \quad (3)$$

and the maximum kinetic energy E_k is

$$E_k = mv^2/2 = m\,(x_o\omega_n)^2/2 \quad (4)$$

By equating Equations (3) and (4) and solving for f_n, there results the familiar equation for natural frequency

$$f_n = \frac{\omega_n}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{K}{m}} = 3.12\sqrt{\frac{K}{W}} \quad (5)$$

The assumption is often made that the dynamic spring constant, which is found from a vibration test, is the same as the static spring constant, which is determined from a force-deflection test. If this is true, then representing the static deflection under load by x_s, there results

$$K/W = 1/x_s \quad (6)$$

substituting Equation (6) in Equation (5)

$$f_n = 3.12/\sqrt{x_s} \quad (7)$$

The use of the static spring constant is not proper in many designs. For example, if the spring is a tightwound helical spring with initial tension, the weght will have to overcome this tension before deflection takes place. Hence the measured static deflection will not indicate the true spring gradient, and the frequency calculated from Equation (7) will be in error.

A more serious source of trouble may occur when static deflection is used as a measure of spring constant for rubber-like materials. Average ratios of dynamic to static stiffness for some rubber-like materials in compression are about 1.5 to 2. Tests of one commercial mounting material revealed that the dynamic to static stiffness ratio was equal to 9. Since a ratio of 9 in stiffness represents a factor of 3 in frequency, it can be seen that static spring constants or static deflections should be used with some caution.

If a vertical sinusoidal force $F_o \sin \omega t$ is applied to the mass, Fig. 1, the ratio e of the applied force to the force transmitted through the spring to the foundation is called the transmissibility. The transmissibility, neglecting damping, is given by

$$e = \frac{1}{1 - (\omega/\omega_n)^2} \quad (8)$$

If instead of applying a periodic force to the mass, the foundation supporting the system is vibrated vertically with a displacement given by $a_o \sin \omega t$, Equation (8) gives the ratio of the maximum absolute displacement of the mass to the maximum displacement of the foundation.

A plot of Equation (8) gives the familiar curve shown in Fig. 2. An inspection of the curve shows that if it is desired either to minimize the force transmitted to the foundation by an unbalanced machine, or to minimize the motion of the mass when the surrounding structure vibrates, the natural frequency of the system should be as low as possible.

As indicated by Equation (5) the natural frequency, and hence the transmissibility, can be made small by making the spring constant sufficiently small. For the simple system shown in Fig. 1, the mass could be readily mounted to provide isolation for almost any practical disturbing vertical frequency.

Unfortunately, there are not many practical mounting problems where the mass can move only in one direction, and where all the excitation occurs only in that direction. This simple theory, therefore, should not be applied directly to the majority of practical engineering problems.

NATURAL FREQUENCIES IN PRACTICAL MOUNTINGS. The majority of mounting problems are concerned with mounting an object that can be visualized as the box shown in Fig. 3. If the box is to be successfully mounted, it will be necessary to keep all the natural frequencies well away from and preferably below the lowest exciting frequency that may exist. Since the number of natural frequencies is equal to the number of degrees of freedom or modes in which the box can move, it is not difficult to deduce the number of natural frequencies the mounted box can have. The following modes of vibration can be expected for mounted apparatus:

1. Vertical vibration parallel to the z axis.
2. Torsional vibration around the z axis.

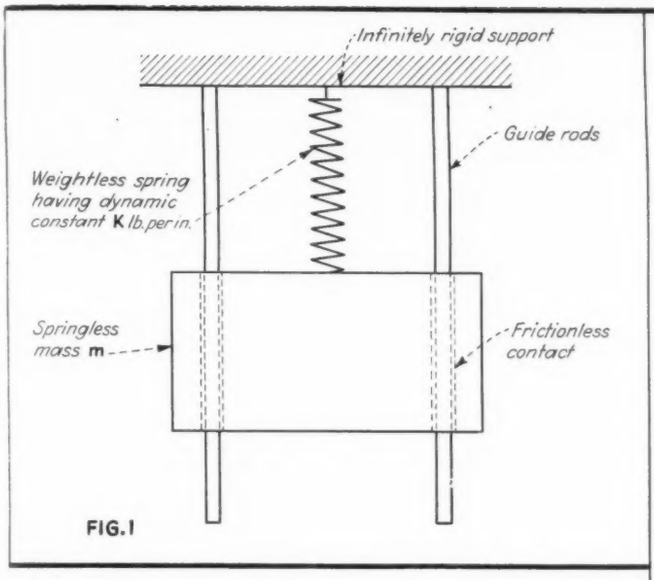


FIG. 1

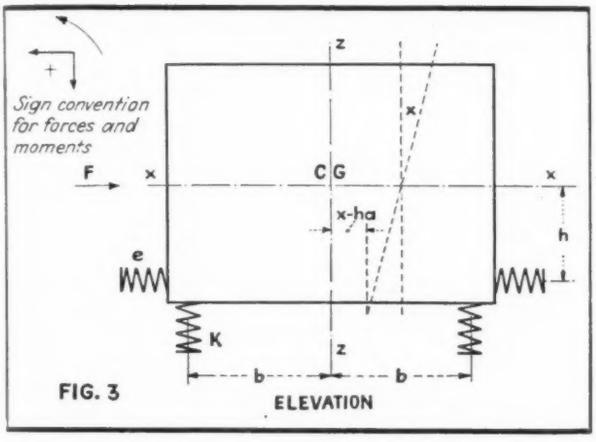


FIG. 3

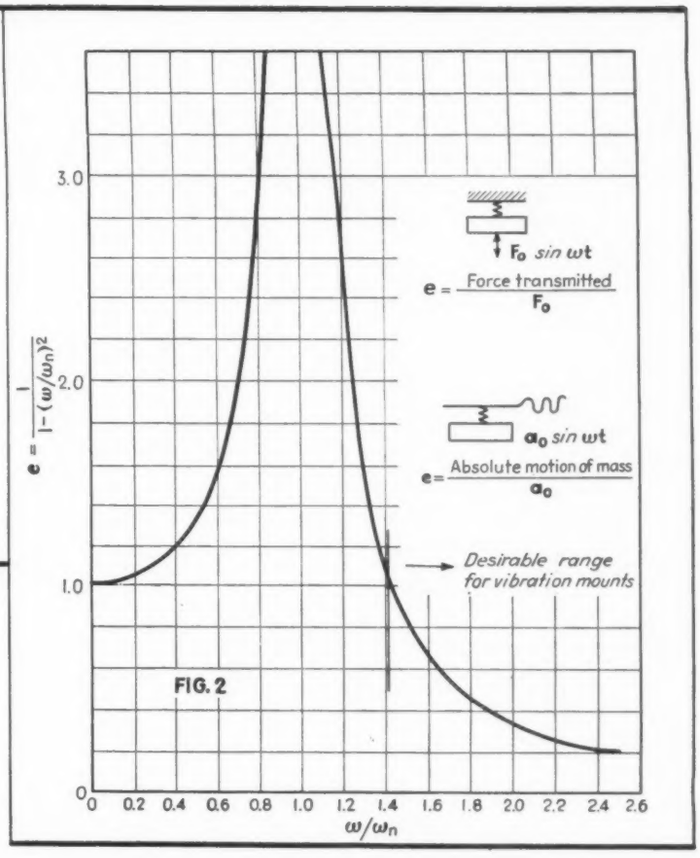


FIG. 2

Fig. 1—Classical single degree of freedom system.

Fig. 2—Theoretical response of simple classical system with no damping.

Fig. 3—Notation for rocking modes of bottom mounts.

3. A low rocking mode in the xz plane.
4. A high rocking mode in the xz plane.
5. A low rocking mode in the yz plane.
6. A high rocking mode in the yz plane.

It should be noted that the box is assumed to be very rigid so that it will not contribute to the spring stiffnesses nor vibrate as a structure.

CASE I. SYMMETRICAL BOTTOM MOUNTS. The arrangement most commonly used is where the mounts are all placed in a horizontal plane, usually the bottom surface of the mounted object. E. H. Hull, *Transactions*, A.S.M.E., Applied Mechanics APM-53-12, and E. H. Hull and W. C. Stewart, *Transactions*, A.I.E.E., Vol. 50, developed equations for this mounting arrangement when the mounts are symmetrically placed about the vertical axis through the center of gravity.

The method that Hull and Stewart used is based on the mechanical impedance concept, which is explained in some detail by Kimball in "Vibration Prevention in Engineering." Kimball shows that if the vibration is sinusoidal steady-state:

Where:

x = linear or angular displacement
ω = exciting frequency, radians per sec.
t = time, sec.

"that the acceleration term, d^2x/dt^2, in the differential equation of motion may be replaced by $-\omega^2x$." This is an extremely powerful tool, since it eliminates the necessity of solving a differential equation, and enables a solution to be obtained by the use of ordinary algebra.

Thus, if the mass in Fig. 1 is acted on by an alternating vertical force $F_o \sin \omega t$, the differential equation of motion would be:

$$m \frac{d^2x}{dt^2} + Kx = F_o \sin \omega t \qquad (9)$$

Using Kimball's rule, the acceleration term $d^2x\ dt^2$ can be replaced by ω^2x, and Equation (9) becomes:

$$-m\ \omega^2x + Kx = F_o \sin \omega t \qquad (10)$$

and hence the displacement is given by

$$x = \left(\frac{F_o}{K}\right)\left[\frac{\sin \omega t}{1 - (m/K)\ \omega^2}\right] \qquad (11)$$

The natural frequency is often of more interest than the displacement. Since with no damping, the displacement theoretically goes to infinity when the exciting frequency is equal to the natural frequency, the natural frequency can be found by setting the denominator of Equation (11) equal to zero. Doing this, the natural frequency of this simple system is given by:

$$\omega_n = 2\pi f_n = \sqrt{\frac{K}{m}} \qquad (12)$$

which is the same as Equation (5).

To apply this procedure to the mounted box shown in Fig. 3 let

F_o = applied force, lb.
C = total horizontal spring constant, lb. per in.
K = total vertical spring constant, lb. per in.
m = mass of box, lb. sec.^{2} per in.
I_y = mass moment of inertia about y axis, lb. in sec.^{2}
ω = frequency, radians per sec.
h = vertical distance from mounts to center of gravity, in.
b = horizontal distance from mounts to center of gravity along x axis, in.
x = horizontal displacement, in.
α = angle of rotation about y axis, radians

Also let C_x represent the horizontal spring constant of the mount in the x direction, and K_z represent the spring constant of the mount in the z direction. Then if the

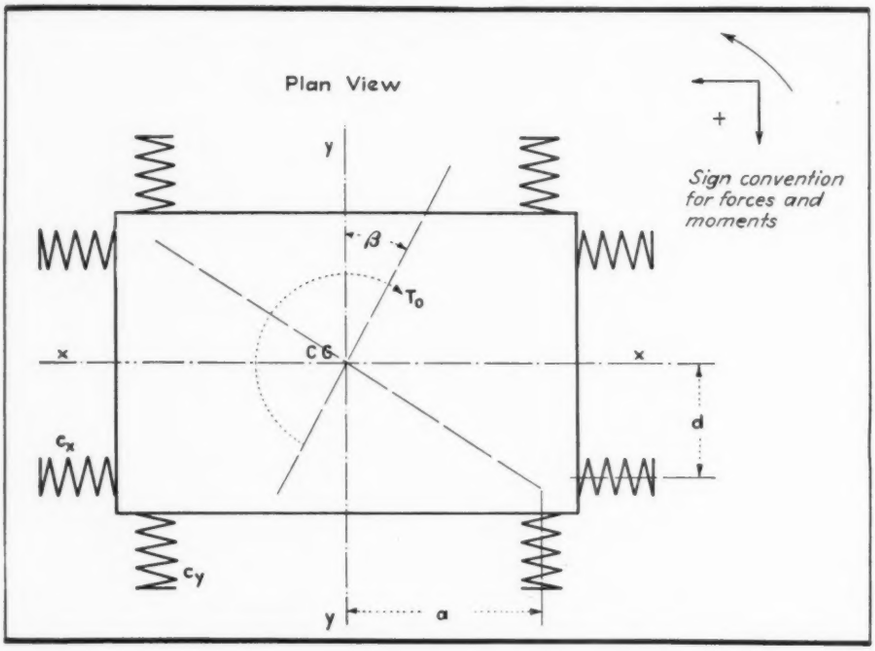


Fig. 4—Notation for torsional mode of bottom mounts.

mounts are symmetrically placed, that is, if the mounts are equi-distant from the z axis in the xz plane and equi-distant from the z axis in the yz plane, the spring constants of the individual mounts can be added together. Hence in the derivation, it is only necessary to consider C, the total horizontal spring constant, and K the total vertical spring constant.

The forces acting on the box in the x direction are:

$-F_o$ = applied force
$c\,(x - h\alpha)$ = spring force resulting from horizontal displacement
$-m\omega^2 x$ = inertia force

If the force F_o is applied in line with the center of gravity along the x axis, the external forces acting on the box plus the inertia force must equal zero, or

$$(C - m\,\omega^2)x - Ch\,\alpha = F_o \qquad (13)$$

In the same manner, the summation of the external moments plus the inertia torque must be equal to zero.

The moments acting on the box are:

$-C(x - h\,\alpha)\,h$ = moment of the spring force caused by horizontal displacement
$+ Kb^2\,\alpha$ = moment of the spring force caused by vertical displacement
$-I_y\,\omega^2\,\alpha$ = inertia torque

The summation of the external moments plus the inertia torque must be equal to zero, or

$$-Chx + (-I_y\,\omega^2 + Ch^2 + Kb^2)\,\alpha = 0 \qquad (14)$$

Values of x and α as functions of the exciting force F_o can be found by solving Equations (13) and (14). But the fundamental problem is to determine the natural frequencies so that resonance is avoided. As in the previous example, resonance will occur when the denominator of the expression for either x or α is equal to zero. Hence the problem becomes that of finding this denominator, and determining the values of frequency for which that denominator will be zero.

From elementary algebra and determinants the denominator for either the expression for x or the expression for α is given by the determinant

$$\begin{vmatrix} (C - m\,\omega^2) & -Ch \\ -Ch & (-I_y\,\omega^2 + Ch^2 + Kb^2) \end{vmatrix} = 0 \qquad (15)$$

Expanding this determinant gives the natural frequencies for motion in the xz plane:

$$(C - m\,\omega^2)\,(-I_y\,\omega^2 + Ch^2 + Kb^2) - (Ch)^2 = 0 \qquad (16)$$

Substituting mr_y^2 for I_y, where r_y is the radius of gyration about the y axis, and expanding Equation (16) results in

$$\omega^4 - \omega^2\left(\frac{C}{m} + \frac{Ch^2 + Kb^2}{mr_y^2}\right) + \frac{CKb^2}{m^2 r_y^2} = 0 \qquad (17)$$

The solution of this quadratic in ω^2, gives the two rocking frequencies in the xz plane

$$\omega = \left\{\frac{1}{2}\left(\frac{C}{m} + \frac{Ch^2 + Kb^2}{mr_y^2}\right) \pm \left[\frac{1}{4}\left(\frac{C}{m} + \frac{Ch^2 + Kb^2}{mr_y^2}\right)^2 - \frac{CKb^2}{m^2 r_y^2}\right]^{\frac{1}{2}}\right\}^{\frac{1}{2}} \qquad (18)$$

A similar equation can be obtained for the rocking frequencies in yz plane, the factors h and b then, of course, correspond to the distance of the mounts from the center of gravity in the yz plane, and the radius of gyration r_x about the x axis is used in place of r_y in the new equation.

The torsional frequency about the vertical axis is obtained by applying a torque T_o, about the z axis as shown in Fig. 4. The symbolic spring C_x represents the stiffness of all the mounts in the x direction. Similarly, the symbolic spring C_y represents the stiffness of all the mounts in the y direction.

a = horizontal distance from the mounts to the center of gravity along the x axis, in
d = horizontal distance from the mounts to the center of gravity along the y axis.
β = angle of rotation about z axis, radians
ω = exciting frequency, radians per sec.

As previously, the inertia torque plus the external torques must be equal to zero,

$$T_o = (-I_z\,\omega^2 + C_x d^2 + C_y a^2)\,\beta \qquad (19)$$

Solving Equation 19 for β and substituting mr_z^2 for I_z, then setting the denominator equal to zero gives the torsional natural frequency ω_T about the z axis as:

$$\omega_T = 2\pi f = \sqrt{\frac{C_x d^2 + C_y a^2}{mr_z^2}} \qquad (20)$$

The vertical natural frequency is given by

$$\omega_v = 2\pi f = \sqrt{\frac{K}{m}} \qquad (21)$$

To reduce the number of variables, it is convenient to express the natural frequencies in terms of the vertical natural frequency. If Equations (18) and (20) for the rocking modes and the torsional mode respectively are divided by $\sqrt{K/m}$, the following equations result:

1. For the rocking modes: Where C is the total horizontal spring stiffness in the plane being considered; b and h are mount distances from the center of gravity in the plane being considered, and r is the radius of gyration about the axis perpendicular to the plane being considered:

$$\frac{\omega}{\omega_v} = \left\{\frac{1}{2}\left(\frac{C}{K} + \frac{Ch^2}{Kr^2} + \frac{b^2}{r^2}\right) \pm \left[\frac{1}{4}\left(\frac{C}{K} + \frac{Ch^2}{Kr^2} + \frac{b^2}{r^2}\right)^2 - \frac{Cb^2}{Kr^2}\right]^{\frac{1}{2}}\right\}^{\frac{1}{2}} \qquad (22)$$

The plus sign in Equation (22) gives the

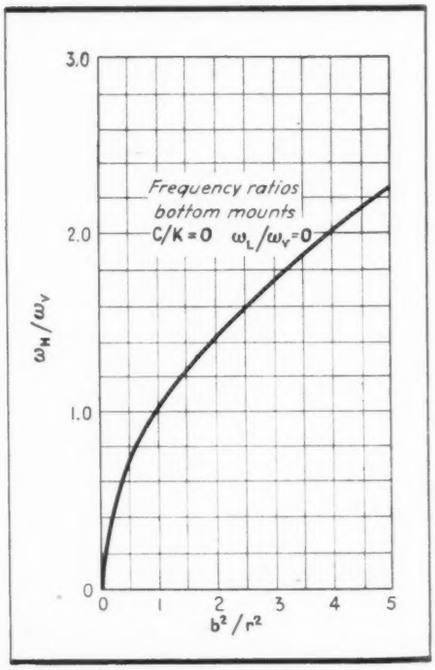


Fig. 5—Ratio of higher rocking frequency to vertical frequency for values of b^2/r^2 when C/K equals zero.

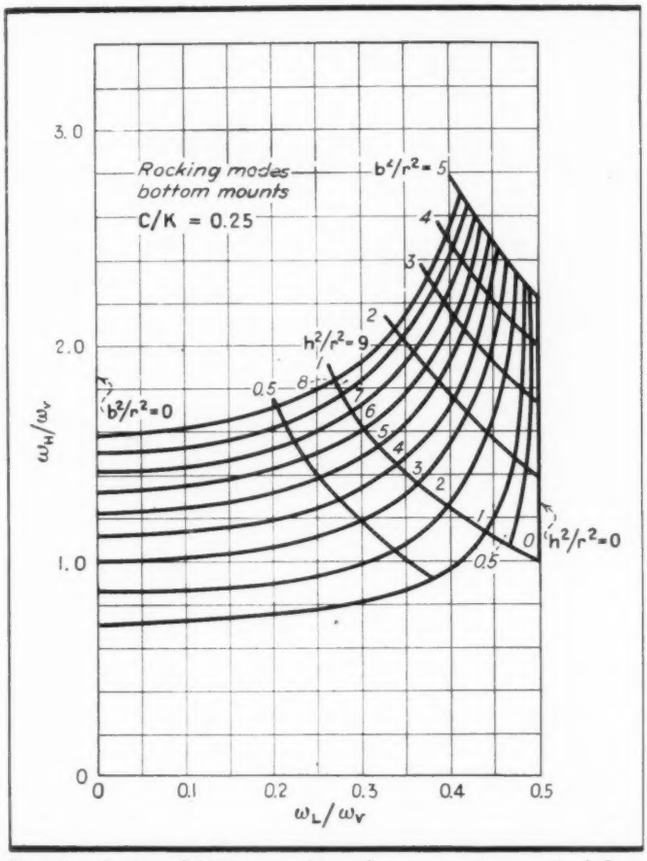


Fig. 6—Ratio of higher rocking frequency to vertical frequency for different values of the ratio of lower rocking frequency to vertical frequency when C/K equals 0.25

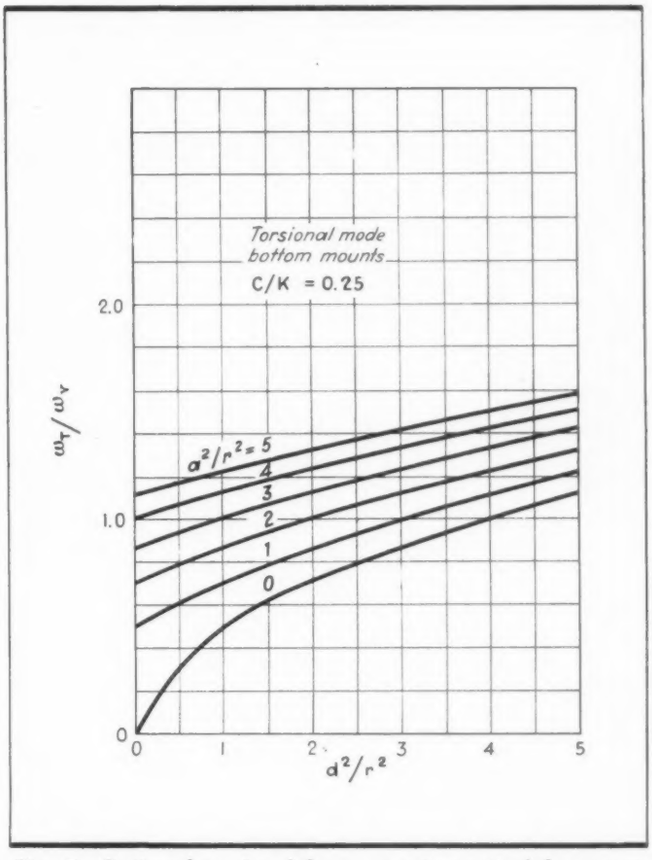


Fig. 7—Ratio of torsional frequency to vertical frequency for different values of d^2/r^2 when C/K equals 0.25 for spring supported, bottom mounted apparatus.

higher rocking mode ω_H, the lower rocking mode ω_L is given by the minus sign.

2. For the torsional mode about the vertical axis:

$$\frac{\omega_T}{\omega_v} = \sqrt{\frac{C_x d^2}{K r_z^2} + \frac{C_y a^2}{K r_z^2}} \qquad (23)$$

If the horizontal stiffness in the x direction is the same as the horizontal stiffness in the y direction, which is true for some commercial mounts, then

$$C_x - C_y = C \qquad (24)$$

and the ratio of the torsional frequency to the vertical frequency is

$$\frac{\omega_T}{\omega_v} = \sqrt{\frac{C}{K}\frac{(a^2 + d^2)}{r_z^2}} \qquad (25)$$

These equations are adaptable to plotting so that a quick estimate of frequencies can be obtained. Curves giving the frequency ratio calculation from Equations (22) and (25) are shown in Figs. 5, 6 and 7, and also in the Reference Book Sheet Section, see pages 159, 161 and 163. Fig. 5 gives the ratio of the higher rocking frequency to the vertical frequency, for C/K equal to zero. The ratio of the higher rocking frequency ω_H to the vertical frequency ω_v is the ordinate, and b^2/r^2 is the abscissa. Since the horizontal stiffness is zero, the lower rocking frequency is zero.

For the chart Fig. 6, which gives the rocking frequency ratios when C/K equals 0.25, the ordinate is the higher rocking frequency ω_H divided by the vertical frequency.

For the chart Fig. 7, which gives the torsional frequency ratio ω_T/ω_v, when C/K equals 0.25, the torsional frequency divided by the vertical frequency is the ordinate, and the abscissa is d^2/r_z^2, the square of the distance from the mounts to the center of gravity along the y axis divided by the square of the radius of gyration about the z axis. *Editor's Note:* Part II of this article, to be presented in the August number of PRODUCT ENGINEERING, will discuss a procedure for isolating vibration in apparatus when the spring mounts are placed in any position about a major axis.

German Finishes Investigated By Naval Technical Mission

QUALITY of external and internal metal and wood finishes in German military planes declined rapidly during the war. By the end of the war, the Germans were uniting parts made of different metals in wings and fuselages without surface control of corrosion. The finishes were investigated by H. L. Acker, of the United States Naval Technical Mission in Europe, who has issued a report on his findings.

The report covers finishes for aluminum alloy aircraft skin and for magnesium metal parts; heat resisting paints; compounds for insulation of dissimilar metal parts; sealing materials for fuel tanks, hulls, floats, and other aircraft components; fabric finishes; and aerodynamic smoothing materials.

One interesting compound noted by the investigator was a putty-like material used for aerodynamic smoothing in the Me 262 and the Me 163, jet and rocket high speed aircraft. The putty compound was applied to the bare metal of the fuselage and wings, sometimes to a thickness of three-eighths inch over laps and joints of the wing. The putty resisted cracking at the seams and seemed to retain a good flexibility, according to the investigator. He was unable to get samples of the product.

The only new raw material found in use by the Germans for the protection of metal parts was Cyclohexanol resin, used in some lacquer finish coats. This material is now being tested by the Navy.

Design Tolerances For Transparent Acrylic Plastics

Practical tolerances for the machining, forming, assembly, and installation of transparent acrylics are discussed together with methods of mounting and fastening. Design considerations when using inserts are included.

SPECIFICATION of tolerances for machined, fabricated or molded acrylic plastic parts raises a number of questions. These plastics, because of their clarity are often used for "see-through" parts (plane inclosures, safety guards, and inspection windows) where optical considerations are more important than mechanical. In these cases, the fabricator or molder should be allowed the greatest possible latitude in dimensional tolerances so that he may use the method yielding the best optical part. For example, the use of air pressure differentials in forming acrylic parts—the so-called free-blowing process—produces parts with optimum optical properties but does not permit holding close contour tolerances, as explained in "Vacuum Forming Speeds Fabrication of Plastic Sheets," PRODUCT ENGINEERING, November 1944, page 745. Arbitrary specifications of unnessarily narrow limits in curvature may force the fabricator to use other methods with a resulting reduction in optical quality and often an increase in fabricating costs.

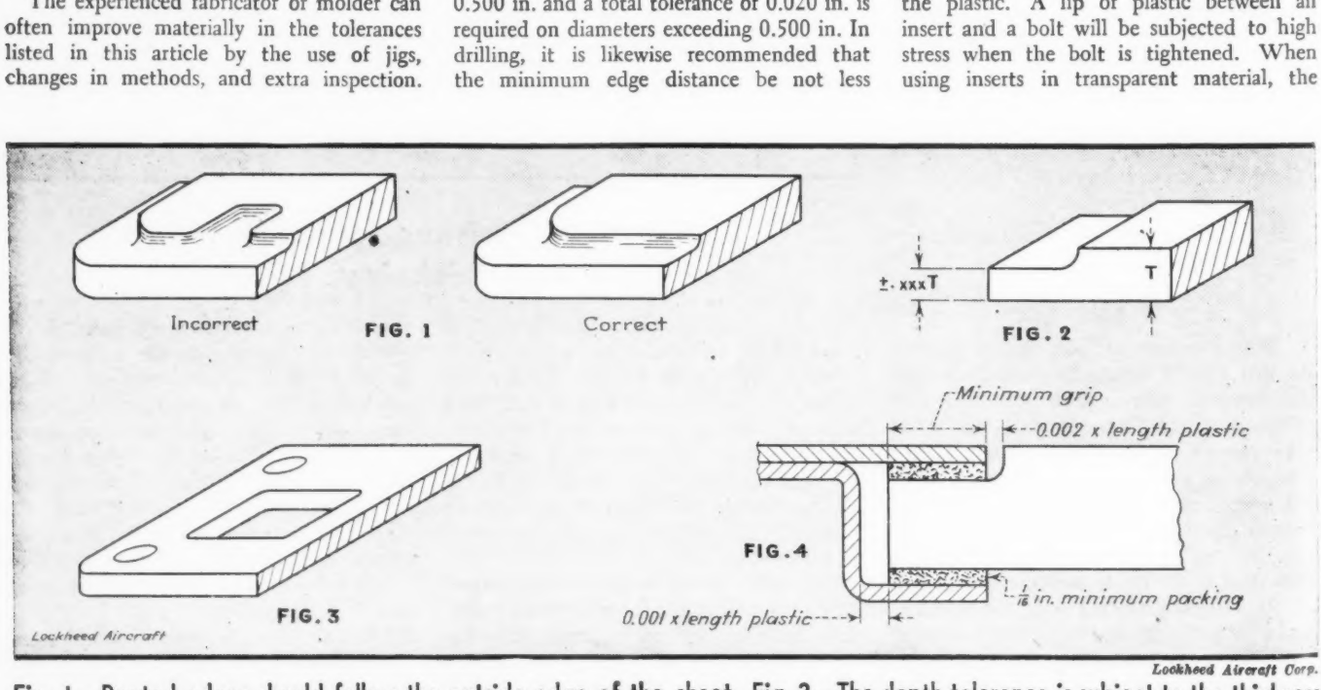
The experienced fabricator or molder can often improve materially in the tolerances listed in this article by the use of jigs, changes in methods, and extra inspection. Unit costs will usually increase accordingly.

One other consideration is the fact that acrylic plastics have a fairly high coefficient of expansion, approximately three times that of most metals and ten times that of ordinary glass, and appropriate allowances should be made for differences in inspection and installation conditions if extremely close tolerances are specified. Unlike many other types of plastics, the acrylics fortunately do not shrink or expand appreciably with humidity changes.

As a general rule, the total or sum tolerance on each dimension specified in this article represents a working tolerance, and, where possible, should be specified as unilateral on drawing.

Transparent acrylic plastics are similar in general machinability to brass and soft copper, but inasmuch as they are notch sensitive, sharp and rough edges should not be specified. Shoulder radii and fillets must be used. Drilled holes can be located within a total tolerance of 0.010 in. A total tolerance of 0.010 in. is allowable on diameters to 0.500 in. and a total tolerance of 0.020 in. is required on diameters exceeding 0.500 in. In drilling, it is likewise recommended that the minimum edge distance be not less than 2.5 or 3 times the outside diameter of the drilled hole. It is not necessary either to break edges around holes or to buff holes. A clean and properly drilled hole, free of chips and cracks, will give maximum pin-load bearing strength.

Although acrylic plastics can be tapped and threaded, Rosán or Helicoil inserts should be specified where frequent assembly and reassembly of parts by threaded connections is required. When molded inserts are to be used they should be designed to allow for sufficient plastic material to give the insert a solid mounting, to permit flow of the material around the insert, and to accommodate differences in expansion and contraction between the metal insert and the plastic. Particularly in compression molding, but also in injection molding, the insert should be made short and sturdy enough so that it will not be broken or dislodged by the flow of plastic. The proportion of depth to diameter should not be more than a 2:1 ratio. Inserts should either project above or be flush with the surface of the plastic. A lip of plastic between an insert and a bolt will be subjected to high stress when the bolt is tightened. When using inserts in transparent material, the



Lockheed Aircraft Corp.

Fig. 1—Routed edges should follow the outside edge of the sheet. Fig. 2—The depth tolerance is subject to the thickness tolerance of the sheet. Fig. 3—Routed cut-outs of various shapes can be made in transparent covers. Fig. 4—Typical channel clamp showing method of mounting and minimum grip.

exterior design of the insert should be considered for appearance sake.

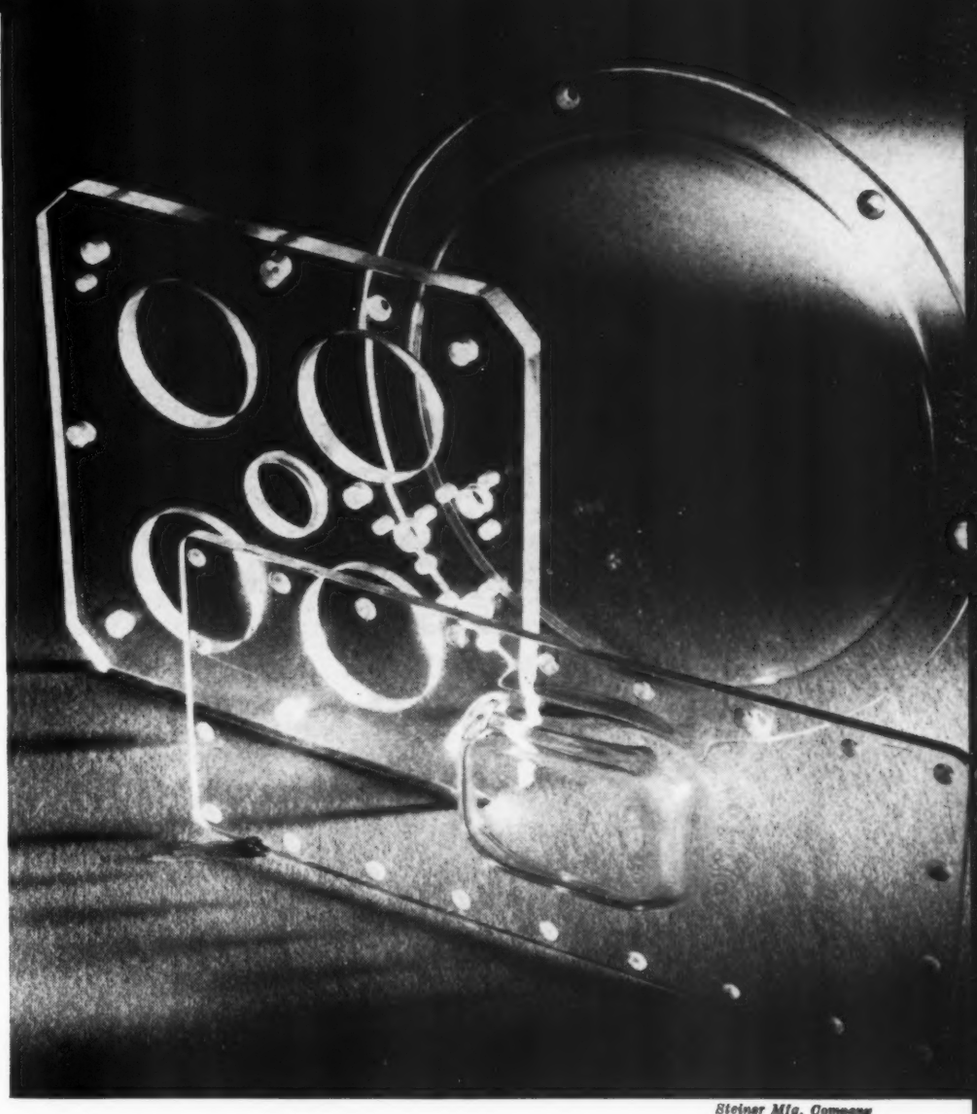
Threads molded in the plastic part can save considerable assembly time, but they increase the cost of the mold. "Molded-in" threads should be coarse and heavy with rounded apexes to reduce the danger of cracking. The thread should not start at the surface of the molding, but at least $\frac{1}{32}$ in. should be allowed to eliminate a feather edge. It is not practical to mold threads into a part except for hole diameters of $\frac{1}{4}$ in. or more. For greatest strength, mounting holes should not be less than the thickness of the plastic piece and preferably farther away from the edge of a molding to allow for flow of material around the pin in the mold. If possible, the hole should pass entirely through the part so that core pins can be supported in both sides of the mold. As a general rule, the depth of the hole should not be more than twice the diameter of the hole. Holes smaller than $\frac{1}{8}$ in. should not be deeper than the diameter of the hole.

In lathe work, such as turning and cut-off operations, transparent plastics can be held to a total tolerance of 0.005 in. Here, as in the case of other machining, shoulder radii and fillets must be generously specified.

In routing and milling, the inside edge of the rout should follow the outside edge of the sheet as shown in Fig. 1. The width and depth of the routing must be kept uniform and a shoulder radius must be allowed in all cases. A tolerance of +0.060 in. and —0.000 in. should be permitted in this operation. The depth of the rout or the toe of the rout can be held to a total tolerance of 0.010 in. However, only one of these depths can be held to this tolerance since the other depth tolerance will always be subject to the thickness tolerance of the sheet as shown in Fig. 2. Routed cut-outs in transparent covers, Fig. 3, can be held to a total tolerance of 0.060 in. in parts over 18 in. and 0.030 in. in smaller parts. Where routed panels are mounted with bolts or rivets, the holes must be kept close to the thick portion of the panel to minimize any bending moment tending to break the panel along the rout.

In sawing, the total linear tolerance applied to flat and formed sheets is 0.060 in. If necessary, lengths less than 12 in. can be held to a total tolerance of 0.030 in. Angular cuts for mating faces can be held to a total tolerance of 2 degrees.

Small fabricated parts bent to a simple two-dimensional bend should have total tolerances of 0.250 in. In small "free blown" domes, for which no dies are used, total contour tolerances may require 0.500 for pieces to 30 in. in diameter and 1.000 in. for longer sections. In fabricating a deeply drawn three-dimensional section, however, the material is literally stretched and thereby thinned down to an extent dependent upon the depth of the draw. Thickness tolerances specified for parts such as these should include allowance for this thinning out beyond the nominal 10 percent thickness tolerance.



Steiner Mfg. Company

Typically machined forms fabricated from acrylic plastic.

The primary consideration for assembly tolerance is the difference in coefficient of expansion between the transparent plastic and the material to which it is mounted. Acrylic plastic has a coefficient of expansion of 0.00005 in. per in. per deg. Fahrenheit.

When plastic parts are attached by bolts, an expansion tolerance in the bolt hole equal to 0.003 in. per inch of panel width must be allowed in addition to the drill tolerances given before. Spacers should be used to avoid localized concentrated loads due to over-tightening; or long-shank bolts or cap nuts should be utilized to make it impossible to bring the mounted pieces closer together than the thickness of the sheet plus a reasonable clearance for thickness variations and for rubber packing. The use of shoulder rivets or spacers would also apply in riveted applications.

Wherever possible, bolting and riveting through holes in the plastic should be avoided. Service experience has shown that installations of this type show a tendency to crack. Channel and clamp installations are usually preferable from the point of view of mass production methods and are definitely superior in distributing stresses. In this type of mounting, the channel should be oversize to permit free linear expansion and contraction of the plastic relative to the frame. The channels should be deep enough to hold the plastic securely despite flexing and thermal contraction. A safe rule is that plastic panels to 12 in. x 12 in. in size should extend into the channel 0.625 in. plus the contraction clearance (0.002 x length plastic); larger panels, 1.000 in. plus contraction clearance as shown in Fig. 4. In calculating these allowances, the linear sawing tolerances of 0.060 in. must be considered. Tolerances of 0.030 in. can be maintained when necessary on panels under 12 in. length.

The location of cemented stiffening ribs on panels can be held to a total tolerance of 0.125 in. and the location of cemented ribs for attaching the plastic assembly to its mounting can be held to a similar total tolerance of 0.125 in.

[Editor's Note: Data for this article furnished by Rohm and Haas Company and Lockheed Aircraft Corporation.]

Torsion Rubber Spring Design With Automotive Applications

A. S. KROTZ
The B. F. Goodrich Company
W. B. FAGEOL, JR.
Twin Coach Company

Fundamentals of spring design and the manner in which the spring medium is related to the more specialized problems of applying the spring to the chassis. Flexibility of the Torsilastic spring, its advantages and analytical and graphical methods of design are discussed.

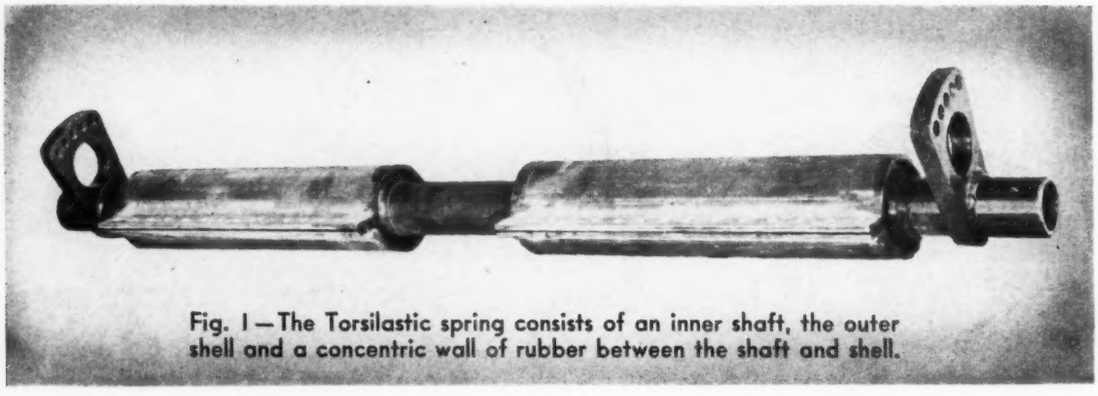


Fig. 1—The Torsilastic spring consists of an inner shaft, the outer shell and a concentric wall of rubber between the shaft and shell.

UTILITY of "Torsilastic" rubber spring has been proved in a wide variety of industrial, commercial and automotive applications. This discussion deals specifically with the design of the spring for use in buses and automobiles but industrial and commercial applications are often just as exacting. The same fundamentals of design apply.

The Torsilastic spring, as the name implies, is a torsion type spring. The parts are: (1) An outer shell; (2) an inner shaft; and (3) a hollow cylinder of rubber bonded to the shell and to the shaft. The shell and shaft can be made of steel or aluminum. Since rubber can be bonded satisfactorily to some brass alloys and to cast iron, these materials are also used for shafts and shells.

A split shell serves three major purposes: First, it permits the application of high pressures between rubber and shell during the curing of the bond. Pressure is necessary to obtain satisfactory adhesion. Second, the split shell allows the rubber to shrink, after cure, without causing residual tension. Third, the half shell can be compressed to a diameter somewhat smaller than its free, room-temperature diameter to place the rubber and the rubber-to-metal bond in a state of radial compression.

The spring is stressed in torsion by anchoring either the shell or the shaft to the chassis and rotating the other member. The total angular movement and the rate of angular movement are two quantities that depend upon the rubber part of the spring. In automotive application both quantities must be designed to suit chassis limitations. A deflection of from 7 to 12 in. under static loading is normal for passenger cars. Less deflection is allowed for commercial vehicles. For example, the deflection is 4¾ in. for many Twin Coach buses. The corresponding angular displacement of the spring is 45 deg. Linear displacement under load for a given angular movement of the spring is made larger or smaller by lengthening or shortening the torque arm.

Wide range of designs will meet specified conditions of deflection under static load. The spring may be long and slender or short and thick to suit chassis requirements, such as clearances and the amount of flexibility desired in the mounting. With arm length, static load and static deflection given, the loading moment and torsional rate of the spring are fixed. A knowledge of the elastic characteristics of such a spring is essential to the procedure in detailed spring design.

A torsional loading curve for a typical spring in automotive service is shown in Fig. 2(A). The graph is practically a straight line at and near the static load point. The steeper slope at light loads is typical and the greater moments at the larger angular displacements is characteristic of some designs, but, for practical purposes, the spring rate, or gradient, is constant throughout the range useful in suspension.

The unloading curve departs from the loading curve, Fig. 2(A). Hysteresis or energy absorbed during the cycle is modified considerably by the time required for the cycle. In road vehicles the spring is dynamically loaded, that is, it is alternately loaded and partially unloaded to undergo oscillation. An angular oscillation equivalent to one-inch compression and one-inch rebound, making a total of two-inch stroke of the road wheel, is a common experience.

Hystersis loss during a two-inch dynamic stroke is so small that the loading and unloading curves almost coincide. This is shown diagramatically in Fig. 2(B) where the two-inch dynamic loop is compared with the larger loop—same as Fig. 2(A)—obtained by static loading.

Two things are revealed by this smaller loop. First, the slope differs from that of the larger loop. This means that the rates at which the torque changes are unequal and may differ by as much as 20 percent between static and dynamic loading. Second, a small amount of energy is absorbed by the 2-in. loop. This means that the spring has

little damping effect. Shock absorbers will be necessary to stop oscillations under dynamic loading.

Dynamic properties of a spring design are readily proved by laboratory oscillation tests. A mass is suspended on a moment arm to produce a prescribed torque on the spring. The mass is excited and the free or resonant period of oscillation observed. The length of the laboratory arm need not duplicate service conditions exactly, for the calculated dynamic rate differs little for the same spring at frequencies from one-half to two cycles per sec. Resonant frequencies are converted into dynamic torsional rates by the pendulum formula,

$$d = (188/f)^2$$

where the deflection d is the nominal length of arc through which the spring turns before it supports the average moment and f is the frequency. Unit torsional rate is obtained by dividing the moment by the subtended angle.

Allowable Stresses

Maximum stress occurs at the bond at the inner diameter of the rubber, although failure of the spring seldom happens from failure of the rubber at this minimum radius. In general, the life of the spring is limited more by fatigue range than by mean static stress. Maximum shear stress may be as much as 200 lb. per sq. in., or even more for some applications. Static stress for springs used in vehicle suspension usually will be between 100 and 150 pounds per square inch.

If a spring is flexed continually from free condition to 300 lb. per sq. in., the life of the rubber is relatively short. If the range is 120 to 130 lb. per. sq. in., the life is longer than if the stress is from zero to 100 lb. per sq. in. Reversing the direction of stress, as from plus 50 to minus 50 lb. per sq. in., gives shorter life than conditions under which the range of stress is likewise 100 lb. per sq. in. but always in the same direction.

The diameter of the spring shaft can be designed by the usual design methods safely to resist the known or estimated moments. Then its length can be computed so that the shear stress in the rubber bonded to it will be some prescribed limit, such as 120 lb. per sq. in. The thickness of the rubber compound that will give a desired torsional rate can then be determined.

Mathematical functions relating rubber thickness and spring rate can be derived as follows: Let L be the length of the rubber cylinder having minimum radius R_1. The same torque T that enters the rubber from the shaft radius R_1 is transmitted through the rubber and delivered to the shell at radius R_2. If S_1 is the unit shearing stress at radius R_1, S_2 that at R_2 and S the unit shearing stress at any radius r between R_1 and R_2, then

$$T = 2\pi R_1^2 S_1 L = 2\pi R_2^2 S_2 L = 2\pi r^2 S L \quad (1)$$

From which

$$S = T/2\pi L r^2 \quad (2)$$

Any layer of thickness dr at radius r, Fig. 3, undergoes an angular movement θ. For small angles, θ equals S/G, where S is the stress and G is the shear modulus. If ψ is the angular deformation, the increment deformation $d\psi$ corresponding to the increment of radius dr, is given by

$$d\psi = \frac{\theta\, dr}{r} = \frac{S\, dr}{Gr} \quad (3)$$

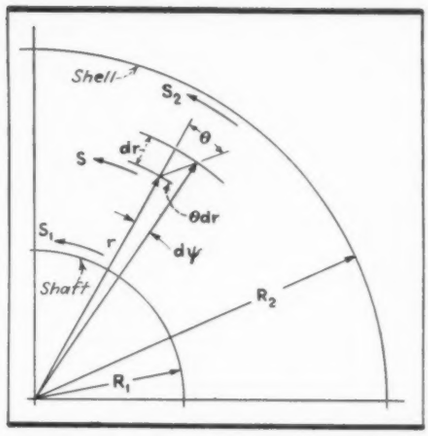


Fig. 3—Relative positions of rubber fibers in stressed state of spring.

Eliminating S between Equations (2) and (3) gives

$$d\psi = \frac{T\, dr}{2\pi G L r^3} \quad (4)$$

Integrating Equation (4) between the limits R_1 and R_2 gives the angular deformation

$$\psi = \frac{T}{4\pi LG}\left[\frac{1}{R_1^2} - \frac{1}{R_2^2}\right] \quad (5)$$

The shear modulus G is the only uncertain factor in the application of Equation (5). Common practice is to assume that G for a rubber compound is defined by the slope of the tangent to the shear curve for small amplitudes of movement. Such a tangent is drawn on the shear curve, Fig. 4(A). It departs considerably from the slope of the curve in the range of actual stress.

Soft rubber will deflect more than harder

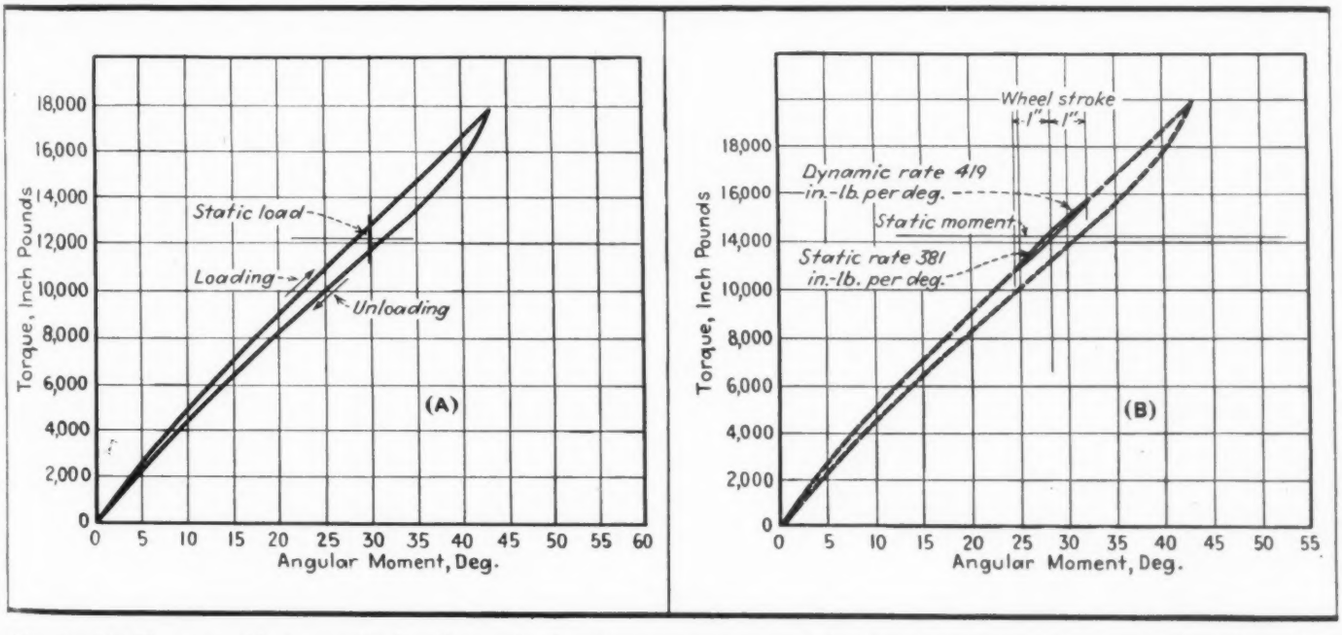


Fig. 2—(A) The spread between the loading and unloading curves represents hysteresis or energy absorbed during the cycle. (B) Under dynamic loading where the range of stress is smaller than that in static loading, the loading and unloading curves almost coincide.

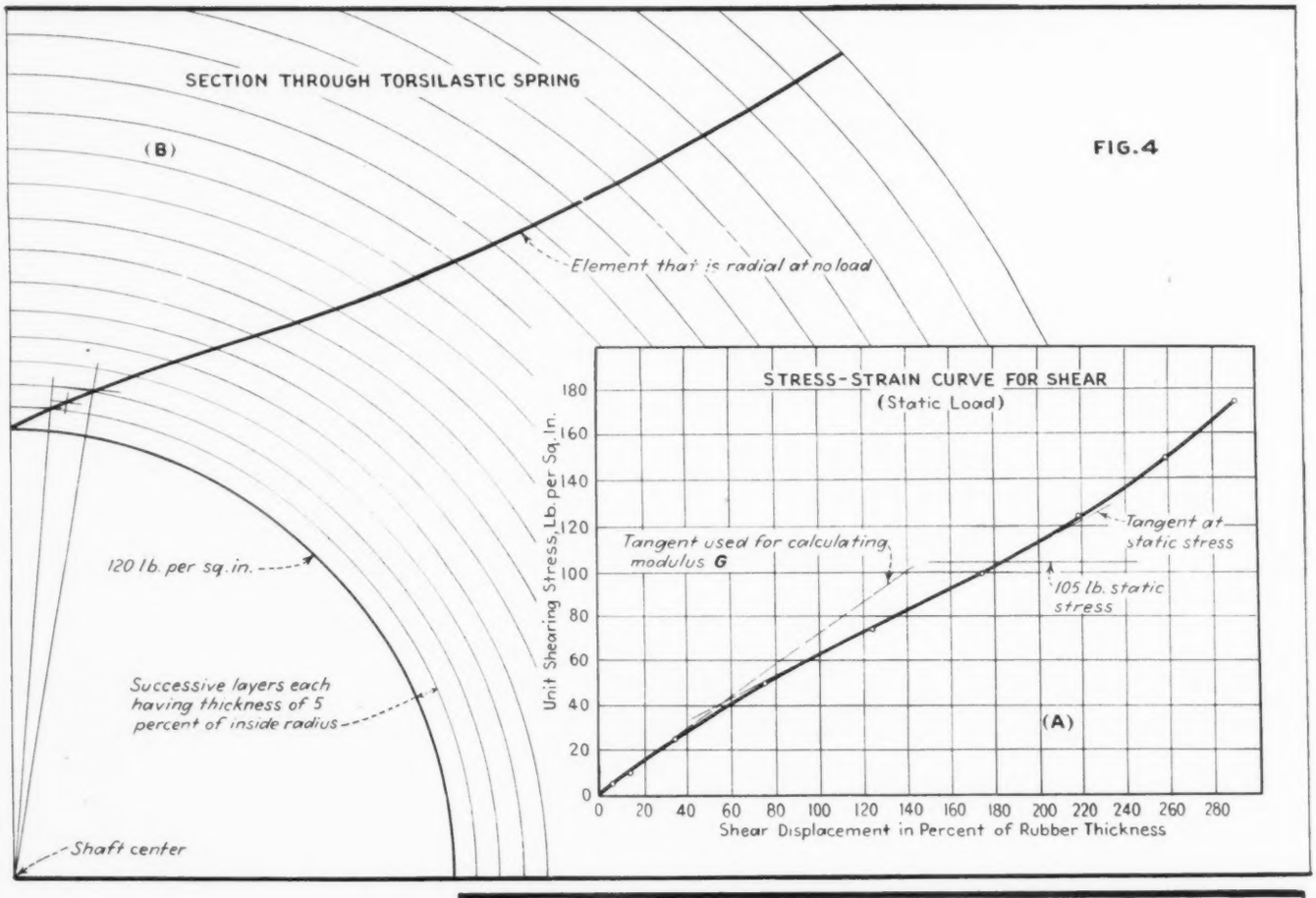

SECTION THROUGH TORSILASTIC SPRING
(B)
FIG.4
Element that is radial at no load
120 lb. per sq. in.
Successive layers each having thickness of 5 percent of inside radius
Shaft center
STRESS-STRAIN CURVE FOR SHEAR
(Static Load)
Unit Shearing Stress, Lb. per Sq. In.
Tangent used for calculating modulus G
Tangent at static stress
105 lb. static stress
(A)
Shear Displacement in Percent of Rubber Thickness

Fig. 4—Graphs such as these—one for each rubber compound—can be used to determine the rubber thickness in springs.

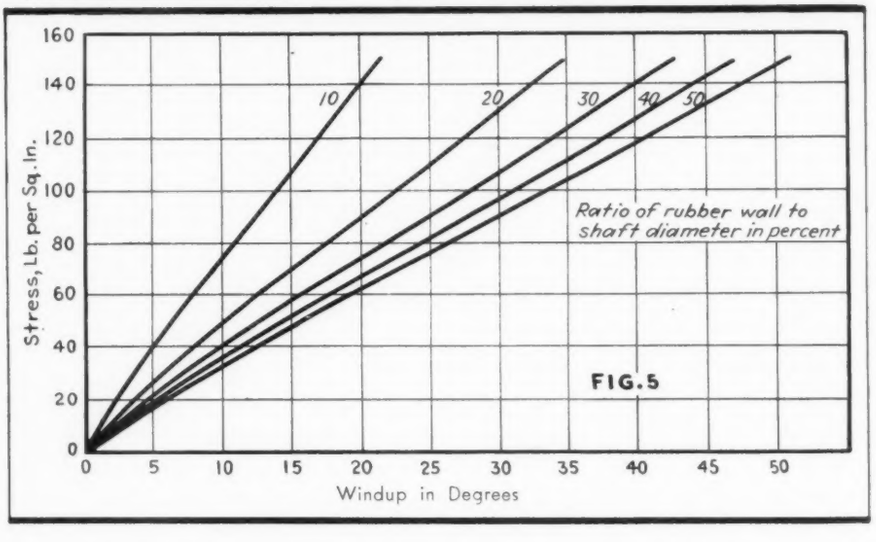


Fig. 5—Graph for 42 durameter stock showing rubber thickness in percent of shaft diameter.

compounds under equal torques. A rubber should be selected to suit the type of service, but generally designs can be calculated for a rubber of 45 durometer if natural, and 50 durometer if synthetic rubber is to be used.

Calculating the thickness of the rubber wall as a percent of the shaft diameter is convenient because all springs having the same thickness in percent of rubber will develop the same shearing stress at the bond between rubber and shaft. If one spring has a 2-in. shaft and a 1/2-in. thickness of rubber, giving a 25 percent wall, and another has a 4-in. shaft and a 1-in. thickness of rubber, each will have the same shearing stress on the bond to the shaft, assuming the angular displacements are equal.

Either the angular rate of the spring or the angular wind-up in the static position can be used in calculating the thickness of the rubber. Static wind-up usually will be less than 45 deg. The graph of spring characteristics, Fig. 5, shows the relation for rubber thickness varying from 10 to 50 percent of shaft diameter. This graph is made for 42 durometer stock. If 50 durometer is to be used, the stress for a given angle is multiplied by 1.37. The multiplying factor is 1.62 for 55 durometer stock.

For dynamic conditions, that is, where the spring is flexed through a full cycle in a second or less, the spring will have a stiffer rate than that shown in Fig. 5 for static conditions. The ratio between static and dynamic conditions depends upon the rubber stock. For natural rubber of 45 durometer hardness, the ratio may be assumed to be 1.25 or the dynamic rate is 125 percent as stiff as the static rate. For synthetic rubber at 50 durometer, a ratio of 1.50 may be assumed.

Graphical Method

The thickness of the rubber can be determined graphically with a fair degree of accuracy. In Fig. 4 (*B*) the rubber ring is divided into successive layers each having a

thickness equal to 5 percent of its smaller radius. These layers can be considered as corresponding to the elementary rings of thickness *dr* in the analytical derivation.

The heavy spiral line represents the position taken under torsional deflection by a theoretical element in the rubber that is radial at no load. In each of the successive layers the distorted element departs from the radial direction by the angle of departure for that stress as obtained on the shear sandwich.

One such graph is all that is needed for each rubber compound to cover any assumed range of unit static stress and torsional rate. The graph is prepared for a stress of 120 lb. per sq. in. at the shaft radius, Fig. 4 (*B*). For lower static stresses it is only necessary to move out to a new radius where the required shear stress exists and strike a new arc to represent the inside diameter of the rubber. The thickness required for any angle of wind-up is always measured in terms of percent of that inside diameter.

Twin Coach Application

Spring design cannot be carried to completion without considering the other members of the suspension. Wherever Torsilastic springs resist linear movement, such as the up-and-down displacements of a road vehicle, a linkage is required to transform the linear motion into angular motion. The Twin Coach suspension illustrates well how such a linkage can be designed to function to advantage with the spring component.

The outer shell is fixed to the axle beam at the center, Fig. 6. Thus the shell has the linear motion. It rises and falls as the wheels roll along the roadway. The lever ends of the spring shaft are attached by means of shackles to the transverse, main-truss supports of the coach body.

The shackle is a forged aluminum link bonded in rubber at the centers about which the linkage rotates during movement. The linkage has no mechanical bearings. There are three points at which the body is insulated from the axle by rubber; that is, by the rubber in the Torsilastic spring and by the rubber at either end of the shackle.

A separate view of the linkage and its kinematics are shown by Fig. 7. The distances between centers and the angularity of the links, Fig. 7 (*B*), are such that the effective lever arm on the spring changes with the load so that equal increments of load cause less deflection as the total load increases. This effected a reduction in floor level displacement by more than an inch between empty and standee conditions in the 44 passenger bus. Fig. 8 shows by curves how the deflection varies with load. The load-deflection curve for the spring alone is almost a straight line through the equivalent range of loading.

Nominal dynamic deflection, Fig. 8, is indicative of the quality of the ride. Not

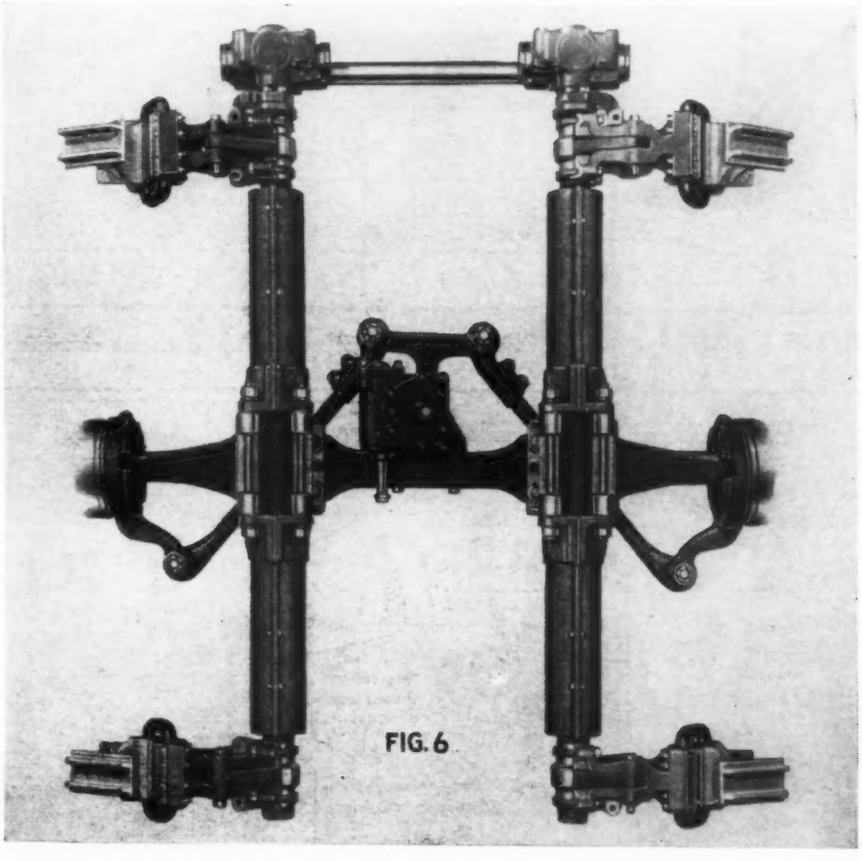
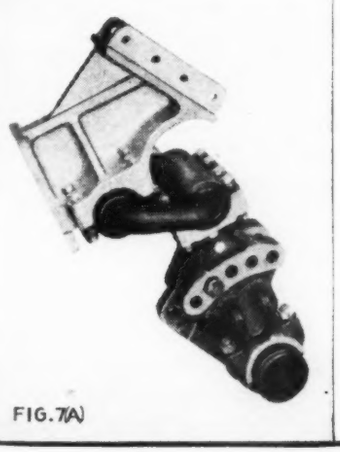


Fig. 6—Two springs are mounted on each wheel axle and transverse to it in Twin Coach applications.

Fig. 7—The linkage between the axle and bus body is designed to modify the load-deflection characteristics of the spring alone so as to improve riding quality of the bus.



Axle Position	Angle α deg.	Wind-up of Top Shackle Bushing, deg.
Unloaded	86	-30
Empty	93	-23
Full Load	116	0
Bump	134	+18

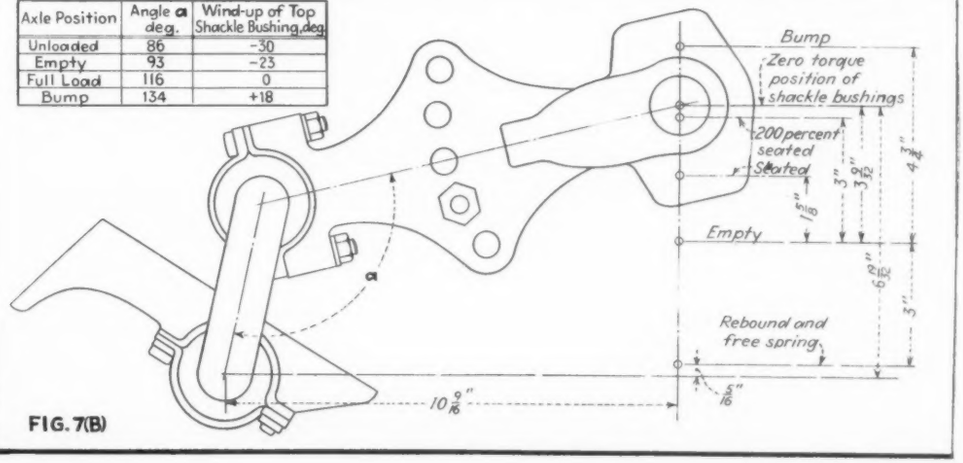


FIG. 7(B)

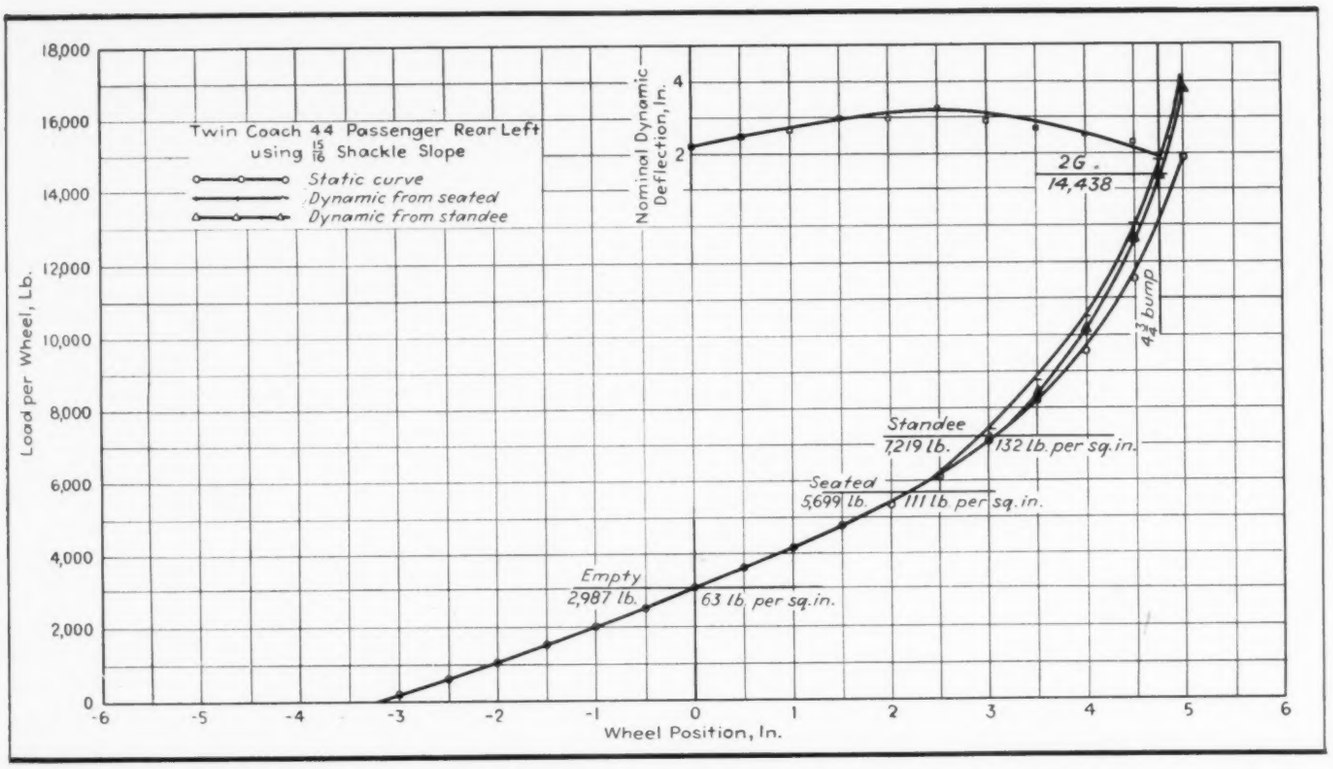
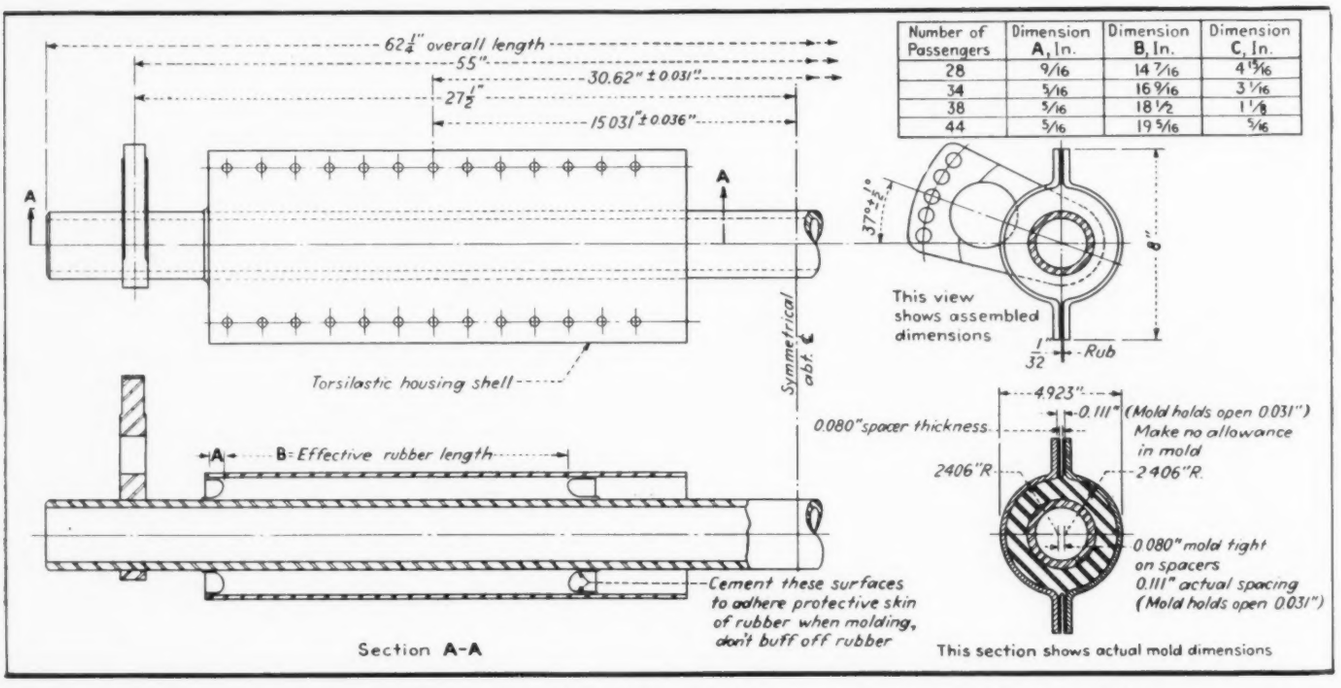


Fig. 8—Curves showing deflections caused by loading from empty to full load under both static and dynamic conditions.



Number of Passengers	Dimension A, In.	Dimension B, In.	Dimension C, In.
28	9/16	14 7/16	4 15/16
34	5/16	16 9/16	3 1/16
38	5/16	18 1/2	1 1/8
44	5/16	19 5/16	5/16

Fig. 9—Details of design indicating how only the length of the rubber is changed to gets springs of different capacities.

only does the spring rate increase slower with load but the over-all ride gives the impression of considerably softer springs, which is attributed largely to the rubber supports and the reduction in harshness and noise level.

Springs of the same dimensions are used on buses of different sizes. Fig. 9 gives details of the spring design, the differences in the sizes being determined by the effective length of the rubber in them. This type of design aids standardization and tends toward economy of fabrication and bus maintenance.

The torque arm on the spring shaft is a sector that serves as an adjustment device. By shifting the pin to different holes in the sector the shackle is raised or lowered relative to the wheel axle. These adjustments are used in leveling the bus floor initially. They are used when parts are renewed or releveling is necessary.

Torsilastic springs are clean, lightweight and simple in design. The spring does not develop squeaks or rattles. There are no bearings to be lubricated or serviced. It reduces noise and vibration. These are a few of the advantages that have led to use of this type of spring in many applications.

ENGINEERING ABSTRACTS

FOREIGN AND DOMESTIC ARTICLES

Remote Control Devices

Foreign Abstract from "Remote Control of Small Electric Switches" in V.D.I.-Zeitschrift, Sept. 16, 1944 page 500.

ADVANTAGES of remote control of electromagnetic switches by a low voltage pilot circuit include: Control conductors are easily insulated, control wires need not follow path of main conductors, and parallel pilot circuits give multistation control.

One type of remote control switch is shown in Fig. 1. The four iron rods *A, B, C,* and *D* are anchored in the non-magnetic walls *E* to form a tilting cage between the faces of four magnetic poles *W, X, Y,* and *Z*. A pusher *F* is held in a neutral position by spring *G* that returns automatically to the position shown after each operation. When magnet *H* is energized, the magnetic circuit is closed through the four iron rods and the iron pusher. A second path indicated by the dash line, is offered at a greater magnetic resistance because of the wider air gap at the pole faces. This magnetic difference causes the pusher to tilt the cage and its mercury switch until the switch contact at *I* is closed.

When magnet *H* is de-energized, the spring returns iron pusher *F* to the neutral position, leaving the iron-rod cage in the closed switch position. At the next energizing of magnet *H*, the cage is tilted in the opposite direction to open the switch.

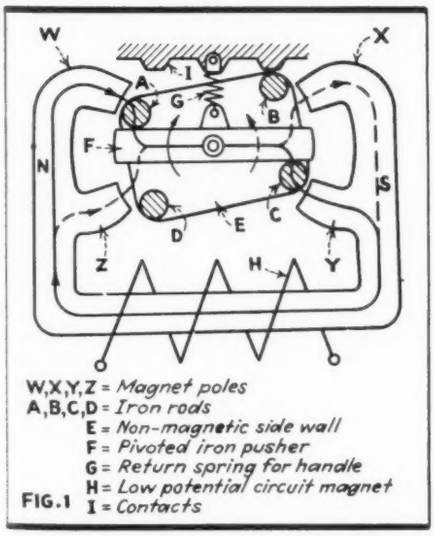


Fig. 1—Remote control switch.

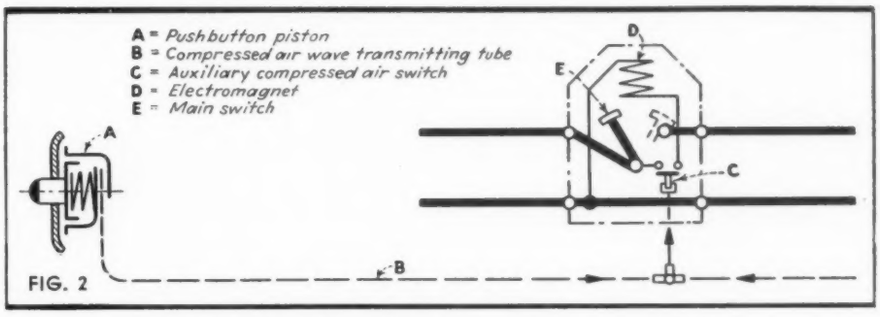


Fig. 2—Remote control by compressed air waves.

A 4 to 6 volt control circuit using one watt will switch up to 750 w. over a distance of 100 meters (approx. 328 ft.).

As shown in Fig. 2, a similar purpose switch controlled remotely by waves of compressed air instead of low potential electric current has been developed in Switzerland. The air wave flow is created by repeated pressing of a spring-opposed pushbutton actuated piston *A*. The waves are conducted to the switch through small metallic tubing or textile hose, *B*. The air waves first close auxiliary switch *C*, which cuts in electromagnet *D* for a brief period, causing the main switch magnet and its mercury switch *E* to tilt into the main circuit position, where it is held by an auxiliary magnet to prevent its return to its initial neutral position. The switch is designed to carry up to 6 amp. of either direct or alternating current at 250 volts.

The controlling compressed air waves are propagated through tubing with an inside diameter of 2 mm. In unprotected locations metal tubing is used. The plastic T-branch connections are joined to the metal by thermoplastic hose connections. In protected locations inside of ducts, thermoplastic hose can be used in place of metallic tubing. It is feasible to locate several pushbutton piston units in the control circuit. The compressed air waves are propagated at a velocity of about 250 mm. per sec. inside of the tubing. Their progress is greatly dampened by the high resistance to their flow. Because of pressure drop, the distance between the pushbutton piston and the switch, should not exceed 20 meters.

Strength of Glass Fiber Laminates

From "The Engineering Properties of Fiberglas Reinforced Plastics," by Games Slayter, Owens-Corning Fiberglas Corp., presented at the annual meeting of the Society of Plastics Engineers, held in Detroit on January 8, 1946.

IN 1942 the Materiel Command, U. S. Army Air Forces, Wright Field, requested manufacturers of low-pressure resins to undertake a cooperative research program on the development of light weight, high strength, easily fabricated, glass fiber reinforced plastics for aircraft structural parts.

While organic fibers and many other "fillers" have been utilized for reinforcing plastics for many years, success had not been obtained in producing structural parts possessing the exact engineering characteristics required for aircraft construction. In undertaking the Wright Field project, two distinct approaches were agreed upon: First, it was decided to limit the investigation to the so-called "contact," or low pressure resins, in order to develop fabricating techniques for large parts that would eliminate expensive high pressure molds and equipment; Second, to utilize the physical properties of fine glass fibers as a reinforcing agent.

During the initial stages of the investigation, it became increasingly apparent that the physical and structural properties of glass fiber reinforced plastics are functions of the physical properties of the glass, rather than

Table I—Strengths Of Engineering Materials

	Yield Strength, lb. per sq. in.	Specific Gravity	Specific Tensile Strength[1]
Structural steel	45,000	7.8	5,800
Monel Metal	100,000	8.9	11,200
Duralumin—24ST	40,000	2.8	14,300
Stainless steel	230,000	7.8	29,500
Piano wire 0.033 in. dia.	320,000	7.8	41,000
Glass fibers[2] 0.00035 in. dia.	270,000	2.5	112,000
Glass fibers[2] 0.00020 in. dia.	330,000	2.5	132,000

[1] Specific tensile strength is obtained by dividing the yield tensile strength by the specific gravity. It is a measure of the strength per unit weight.

[2] Commercial glass textile fibers range from 0.00020 to 0.00035 in dia.

of the resin. The properties of some of the more common engineering materials were compared with those of commercial glass fibers. Table I gives such a comparison.

While the physical properties of various resins, without reinforcement, vary considerably, the values for a typical cast resin, shown in Table II, are sufficiently representative.

The moisture absorption of various reinforcing materials at 75 deg. F., and at relative humidities of 40 and 80 percent, is shown in Table III.

Absorption of moisture causes organic materials to swell; these materials shrink when they dry. These phenomena influence the dimensional stability of plastics products in which they are employed as reinforcement. Since glass is non-porous, its dimensions are not affected by the presence or absence of water in the vicinity.

When glass fibers are used for plastics reinforcement, they may be so oriented in the structure as to take specific loadings economically. It is thus possible to design and fabricate a structural part in the most efficient manner. For example, if the fibers are incorporated in the plastic unidirectionally, (parallel laminated), maximum tensile strength will be developed in the direction of the fibers and minimum strength at right angles to them. If the fibers are "crosslaminated" (laid at right angles to each other), strength will be equal in both directions, and only slightly less on the axes 45 deg. from the direction of fiber. They can also be so oriented as to give uniform strength in all directions.

Strength values developed by commercial glass fiber reinforced plastics are given in Table IV for cross and unidirectional glass laminates in tension, compression and flexure. Since the designer of lightweight equipment is more interested in strength per unit weight than in strength per square inch, these values have been reduced to a common weight basis by dividing the various strengths by the specific gravities of the material, and are reported as "specific" strengths. These values represent strength per unit weight. For comparison, similar values have been presented for a high strength aluminum alloy (24ST), and for structural steel.

As the work progressed, it became apparent that properly constructed glass laminates possess impact resistance of a high order. Analysis of their structure shows why this should be true. Glass in massive form does not show surprising physical properties. When it is drawn into fine fibers, however, it develops an entirely different range of properties high strength, low modulus of elasticity (as compared with metals), and a three percent true elastic deformation. When material possessing these properties is imbedded in a soft material, such as a resin, they are capable of absorbing the kinetic energy of an impinging mass and they develop a high impact resistance. In Table V are given values of impact resistance (Izod test) and modulus of elasticity, and in Table VI are shown values of relative energy absorptions for various materials, up to the point of failure.

Table VI—Energy Absorption Capacity In The Elastic Range

	Percent Elongation	Tensile Strength	Relative Energy Absorption
Stuctural steel	0.2	45,000	9,000
24ST—Duralumin	0.4	40,000	16,000
Hard rubber	3.0	15,000	45,000
Glass fiber reinforced plastics:			
Cross laminated	2.0	55,000	110,000
Parallel laminated	2.0	77,000	154,000
Glass fibers, 0.00020 in. dia.	3.0	330,000	990,000

In working with metals, the engineer cannot easily change their modulus of elasticity. Since a glass fiber-plastic combination constitutes a two-phase system, it is possible to design a desired (apparent) modulus in the finished structure, over a wide range of values. This is done by controlling the amount of glass, the type of weave, the orientation of the fibers within the laminate, and the type of resin employed.

The strength of many materials is adversely affected after prolonged immersion

Table II—Properties Of A Cast Resin

Tensile strength	9,000 lb. per sq. in.
Specific gravity	1.3
Specific tensile strength	6,900
Compressive strength	25,000 lb. per sq. in.
Flexure	25,000 lb. per sq. in.
Modulus of elasticity	0.4 x 10^6 lb. per sq. in.
Impact (Izod)	0.5 ft. lb. per in. of notch

Table III—Moisture Absorption of Reinforcing Materials at 75 Deg. F.

	40 Percent R. H.	80 Percent R. H.
	Percent	Percent
Glass fibers	0.2	0.4
Asbestos	0.4	0.8
Rubber	0.5	1.0
Linen	4.0	8.5
Cotton sheeting	5.2	11.6
Rayon	7.6	14.5
Wood	10.2	19.6

Table IV—Comparative Strength Properties

	Tension lb. per sq. in.	Compression lb. per sq. in.	Flexure lb. per sq. in.	Specific[1] Tension	Specific[1] Compression	Specific[2] Flexure
Gross glass fiber reinforced laminates	55,000	54,000	84,000	31,500	30,800	27,400
Parallel glass fiber reinforced laminates	77,000	68,000	113,000	44,000	38,800	36,800
24ST Aluminum	40,000	43,000	64,000	14,300	15,300	8,200
Structural steel	45,000	45,000	45,000	5,770	5,770	740

[1] Specific tension and specific compression are obtained by dividing the strength values by the specific gravity of the material, to reduce them to a strength-weight basis.

[2] Specific flexure, by dividing the flexure by the specific gravity squared.

Table V—Comparative Properties

	Impact, ft.-lb. per in. Izod	Specific Impact	Modulus of Elasticity tension 10^6 lb. per sq. in.	Specific Modulus of Elasticity, tension 10^6 lb. per sq. in.
Cross glass fiber reinforced laminates	30	17.1	2.5	1.4
Parallel glass fiber reinforced laminated	54	31	4.2	2.4
24ST Aluminum	24	8.6	10.5	3.75
Structural steel	45	5.8	29	3.7

in water. Loss in strength under such conditions can be counteracted by applying a water-repellant, such as a silicone oil, to the glass fibers prior to incorporating them in the plastic. Immersion and exposure tests have indicated that the glass fiber laminates withstand these conditions to a high degree, limited by the ability of the resins to resist such corrosion.

British Industry and Research

From "Industry and Research—How research is organized and financed, and how it may be adopted profitably by any firm, however large or small" in *Mechanical World and Engineering Record*, March 29, 1946, Published by Emmott and Co., Ltd., 31 King St., West, Manchester 3, England.

EXTRACTS are published from papers presented at the conference on Industry and Research organized by the Federation of British Industries and held in London on March 27 and 28. The conference took as its leading subject the application of science in industry and the part that research is playing and can play in promoting industrial efficiency, exports, full employment and a higher standard of living.

The papers give an insight into the practical problems of instituting and using research methods and show how research methods can be used to advantage throughout the whole scale of industrial activities, even by the smallest companies. The titles and authors of the papers are as follows: "The Firm Without a Research Department" by Sir E. Raymond Streat; "Research and Quality" by J. R. Hosking; "Research and Production Costs" by A. Healey; "Conversion of the Results of Research into Production" by C. C. Paterson; "How New Industries Arise" by R. E. Slade; "Modernization of Processes and Plant" by C. H. Davy; "The Part Co-operative Research Can Play" by A. J. Philpot and "The Firm With a Research Department" by P. Dunsheath.

New Synthetic Lubricants

From "Properties and Uses of Some New Synthetic Lubricants" by J. M. Russ, Jr. Carbide and Carbon Chemicals Corp., 30 E. 42nd St., New York 17, N. Y. Presented at New York Section of the American Society of Lubrication Engineers, March 15, 1946.

TWO SYNTHETIC LUBRICANTS, designated as an "LB" series and a "50-HB" series, are described. They are synthesized from natural or other hydrocarbon gases as the raw materials. The synthetic lubricants contain no petroleum oils, differing from them chemically. The "LB" series is essentially insoluble in water. The members of the other series are soluble in water at room temperature. Both series are being produced and marketed under the trade mark "Ucon" by Carbide and Carbon Chemical Corporation.

The lubricants may be prepared in any desired viscosity without the blending of oils of higher and lower viscosities, but blends of the synthetic products are optional. The slope of the viscosity-temperature curve decreases somewhat as the viscosity increases. The lubricants contain no wax or any additives to depress the pour point. Both series have little or no effect on natural and synthetic rubbers.

The "LB" series is better suited for the lubrication of machinery in general, including internal combustion engines. Lubricant "LB-300" was tested extensively in automotive service. Some of the observations were as follows: Clean engines remained essentially sludge and varnish free. Satisfactory low-temperature cranking and starting were experienced in engines operating in low-temperature regions. Average lubricant consumption compared favorably with petroleum oil consumption. The viscosity change as the consequence of oxidation and thermal decomposition was slight even under long mileage operation. Wear of engine parts and bearing composition with the synthetic were comparable to experience with petroleum oils. No clogging of oil screens was observed in over one hundred vehicles of a commercial fleet. The synthetic lubricant did not adversely affect gaskets and fiber timing gears. Both series are useful as hydraulic fluids or as components of them.

Control Transformers

From a paper, "Standardized Control Transformers," by E. E. Opel, electrical engineer, National Automatic Tool Company, Inc., presented at the Westinghouse Machine Tool Electrification Forum, April 9, 1946, Pittsburgh, Pa.

SIZES AND RATINGS of control transformers now vary with each manufacturer to such an extent that in many applications the installation of a built-in transformer requires special engineering. If uniform characteristics, sizes, and shapes can be agreed upon design can be simplified.

Table I—Suggested Standard 60 Cycle Control Transformers

Volt-ampere rating with 440/220 v. primary, 110 v. secondary			
NMTB* and NMA	Genera Electric	Dongan	Westing-house
50	75	50	50
100	150	100	100
200	250	150	150
300	350	250	250
500	500	500	500
750	750	750	750
1,000	1,000	1,000	1,000
1,500	1,500	1,500	1,500

*National Machine Tool Builders and National Manufacturers' Association

Table II—Ampere Loads of 110 Volt 60 Cycle Contactors and Solenoids

Coil	Inrush Amp.	Sealed Amp.	Ratio Inrush amp. / Sealed amp.
00	0.9	0.24	3.8
0	1.59	0.27	5.8
1	1.73	0.32	5.4
2	4.45	0.80	5.6
3	7.27	1.45	5.0
207	0.96	0.22	4.4
209	4.6	0.52	8.8
210	9.2	1.0	9.2
211	17.9	1.5	11.9
206	49.6	3.5	14.2
212	64.4	4.6	14.0
213	114.0	6.4	17.9

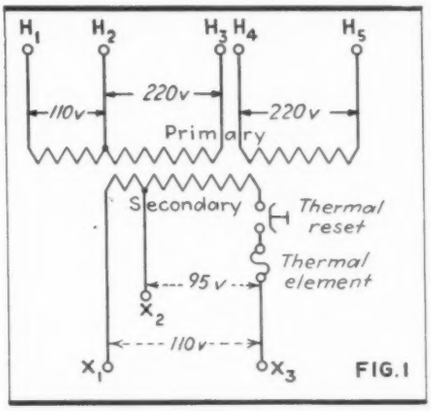


Fig. 1—Special control transformer for various voltages.

A compromise must be made between the short, wide transformers necessary for shallow cabinets and those that are tall and thin for deep cabinets; perhaps by a transformer that can be either end mounted or side mounted. Length and width seem to be less important than depth. Practical depth limits appear to be:

200 volt-amperes—3.5 in.
1,000 volt-amperes—5.0 in.
2,000 volt-amperes—7.0 in.

Two lines of stock control transformers probably will be needed:

1. A standard line rated at 440/220-110 volts; low priced, high production. See Table 1.

2. A special rating line for odd power supplies, chiefly foreign; lower production, higher priced.

Special voltages require special transformers. The transformer in Fig. 1, designed by the Brown & Sharpe Manufacturing Company engineers, includes many of these special voltages in a single unit, see Table III.

Voltage regulation is one of the main considerations in the selection of control transformers. A 500 volt-ampere transformer with good regulation may do a better job than a 750 va. transformer with poor regulation. Referring to the hypothetical regulation curves in Fig. 2, by assuming a load of 25 amp. and following the 25 amp. line

TABLE III—Voltages Obtainable From Transformer in Fig. 1

Cycles	Primary			Secondary	
	Voltage	Lines on	Connect	Voltage	Lines on
60	550	H_1–H_5	H_3 to H_4	110	X_1–X_3
	440	H_2–H_5	H_3 to H_4	110	X_1–X_3
	220	H_2–H_3	H_2 to H_4; H_3 to H_5	110	X_1–X_3
50	550	H_1–H_5	H_3 to H_4	95	X_2–X_3
	440	H_2–H_5	H_3 to H_4	95	X_2–X_3
	420	H_2–H_5	H_3 to H_4	91	X_2–X_3
	400	H_2–H_5	H_3 to H_4	100	X_1–X_3
	380	H_2–H_5	H_3 to H_4	95	X_1–X_3
	220	H_2–H_3	H_2 to H_4; H_3 to H_5	95	X_2–X_3

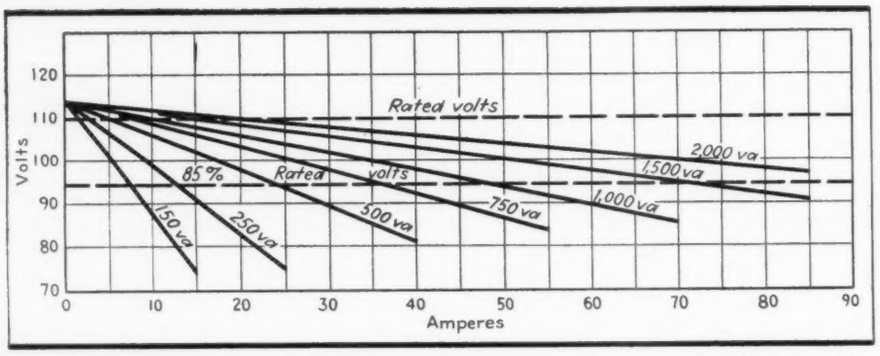


Fig. 2—Typical regulation curves for control transformers of different volt-ampere capacities.

vertically until the 85 percent ordinate is reached, it is evident that a 500 va. transformer is sufficient. Ampere loads can be determined from Table II. It is significant that the inrush currents are from five to ten times the sealed amperes in all three types of load: Contactor coils, solenoid coils, or lamps. Certain coils become energized after the remaining apparatus is operating. The total load then becomes the sum of the amperes in the sealed equipment plus the inrush current developed by the closing coils. The transformer size can be determined from this total.

Either a fuse or a hand reset circuit breaker should be furnished on the low voltage side of the transformer. There is some preference for the circuit breaker since it provides protection against sustained overloads as well as against short circuits.

No inclosure is necessary to protect the transformer.

Both the standard and the special lines of transformers should have the same mounting dimensions with screws accessible from the front.

Terminals should be furnished, preferably of the clamp type. They should be separated so that the high-voltage leads are at one end and the low-voltage at the other.

The name plates should give complete information such as: Volts, volt-ampere capacity, cycles, catalogue number, wiring diagram, and maker's name.

Plastics for Dielectric Applications

From "New Plastic Composition for Dielectric Applications," by W. C. Goggin and R. F. Boyer, presented at the annual meeting of the American Chemical Society in Atlantic City, N. J. on April 11, 1946.

THE WIDESPREAD APPLICATION of electronic equipment in the recent war required development of new types of plastic materials. In general these materials were required to have rather well defined dielectric characteristics such as power factor, dielectric constant and volume resistivity over certain ranges of frequency and temperature. Coupled with these electrical specifications was rather rigid mechanical performance, including extremes of temperature, humidity and impact strength.

One such development is seen in the special ethyl cellulose formulations developed for the proximity fuze. Here the first requirement was impact strength sufficiently great for the fuse to be fired as part of a projectile, and electrical properties suitable to permit operation of the electronic equipment housed in the ethyl cellulose case.

Another important development was a styrene-divinyl benzene copolymer manufactured in the form of cast rods. From these were machined small insulators used on the end connectors of coaxial cables. The requirements here were electrical properties equivalent to those of polystyrene, coupled with a heat distortion temperature of 100 deg. C. or higher.

Synthetic casting resins to replace unavailable tung oil also were prominent. Here the main function was to protect electronic components against mechanical shock and moisture, the usual method being to impregnate the windings of coils and transformers with the resin. A styrene monomer base suitably modified with resins and fillers found application in two such casting resins, one required moderate electrical properties in the cured resin, the other requiring exceptionally low dielectric loss.

Finely divided powder obtained as a by-product from the centerless grinding of styrene-divinyl benzene copolymer rods is a good filler for such casting resins, and when added in sufficient quantity, forms a paste or putty of electrical grade. Similarly, these liquid casting resins serve as a vehicle for powdered material of high dielectric constant, such as titanium dioxide.

The problem of radomes, or housings to protect radar equipment, also placed special demands on dielectric materials, again as a combination of low electrical losses and high mechanical strength. Extremely fine polystyrene fibers, applied in mat form onto molds, were fused into large tough coherent structures with only moderate heat and pressure. Unicellular polystyrene foam, with a dielectric constant approaching that of air, was also found suitable for such uses.

Special resins were developed for use in fiberglass laminates. Although the dielectric properties of the glass are usually dominant in these composite laminates, it is desirable to have a resin with the lowest possible dielectric constant and power factor, as well as good moisture resistance. Modified styrene-base resins were able to supply this need.

Piezoelectric Equations

Foreign Abstract, condensed from the article "On the Theory of Piezoelectric Effect," by L. Gutin in Zhurnal eksperimentalnoi i Teoreticheskoi Fiziki, (Russia), 1945, No. 7.

Consideration of the equations for piezoelectric effect suggests the introduction of two systems of mechanical constants: Elastic and electroelastic.

The equations of axial vibrations of piezoelectric rods and plates and some consequences related to their resonance frequencies are considered. An exact equivalent electromechanical network, for the case of longitudinal vibrations, taking into account the effect of air-gaps and mechanical loads is given.

GENERAL EQUATIONS OF PIEZOEFFECT. Where:

P'_i = Polarization caused by voltage but without field

d_{ik} = piezoelectric moduli

X_k = components pf the tensor of voltage
x_i = component of deformation (in absence of voltages)
E_k = voltage in crystal when deformation of crystal is prevented

the author proves in his theoretical discussion that the equations

$$P'_i = d_{ik}\ X_k \text{ and } x_i = d_{ik}\ E_k$$

may be taken as fundamental equations of piezoeffect.

PIEZOELECTRIC EFFECTS OF QUARTZ Where:

E_x = voltage of the electric field with straight piezoeffect.
P_x = polarization
ϵ_{11} = piezoelectric constant for quarts
E_{11} = dielectric constant
X_x = voltage component along one of the electric axes.

$$E_x = -\frac{4\pi P_x}{E_{11}} = -\frac{4\pi\epsilon_{11}}{E_{11}}\ X_x$$

PIEZOELECTRIC EFFECT OF SIEGNETTE SALT. Where:

d_{14} = piezoelectric moduli
S'_{22} = elastic modulus along axis y' of the crystal
y' = axis obtained by turning 45 deg. around axis X, which is crystallographical axis a
Y'_y = voltage component

$$E_x = -\frac{2\pi d_{14}}{S'_{22}\ E'_{11}}\ Y'_Y$$

Similar formulas are described for:

1. Axial vibrations of a quartz rod, longitudinal piezoeffect.
2. Vibrations of a quartz plate, longitudinal piezoeffect.
3. Electromagnetic network of piezoelectric crystal:
(a) Vibrations with longitudinal piezoeffect,
(b) Vibrations with latitudinal piezoeffect.

Lead Electrodes

From "Reproducibility of Lead Electrodes" by Roger G. Bates, Murray Edelstein, and S. F. Acree, in *Journal of Research of National Bureau of Standards*, February 1946.

LEAD IS A SOFT METAL and anneals spontaneously at room temperature. There is evidence, however, that the thermodynamic properties of stick lead differ from those of electrolyzed crystals, which are presumably strain-free.

Results of a study of the reproducibility of four types of solid lead electrodes are reported. The effects of surface condition and of air dissolved in the solutions used to compare the electrodes were investigated. Stick lead, etched in a solution of lead nitrate and nitric acid, forms very reproducible electrodes, particularly for use in an air-free solution of lead acetate or lead perchlorate.

The electromotive force between 8 percent lead amalgam and sticks cast from the NBS Standard Sample of lead, 49b, and "spectroscopically pure" lead was determined at 0 deg. to 60 deg. C. No difference between the two kinds of metal was apparent. The emf, E, in international volts is given as a function of centigrade temperature, t, by the equation,

$$E = 0.005347 + 0.0000201\ t.$$

and the differences at 25 deg. C. in free energy, ΔF; entropy, ΔS; and heat content, ΔH, between solid lead and saturated lead amalgam were found to be —1129 international joules, 3.9 international joules per deg., and 29 international joules, respectively. These quantities are in good agreement with the constants earlier assigned to electrolyzed lead crystals.

Combating Noise in Mechanisms

Foreign abstract condensed from V.D.I. Zeitschrift, January 9, 1943, page 22.

THE DEMAND for noiseless or nearly noiseless electrically-driven typewriters and bookkeeping machines places certain requirements on the drive of these precision mechanisms. Shock and frictional loading must be avoided, not only because of the noise they cause, but also because of the resulting interference with proper meshing of gears and chain drives. The high-speed ratios and short distances between shaft centers cause accelerations and decelerations that result in shock.

Since the effect of shock increases with the modulus of elasticity, it is desirable to utilize light weight materials in the construction of such machines.

It is also possible to achieve noise reduction by structural means. For instance, a nearly noiseless worm gear drive can displace a noisy link chain drive as shown in Figs. 1 and 2. In this drive consisting of a single electric motor, equipped with two transmission shaft extensions, one for driving a typewriter and the other for driving a bookkeeping machine, noise was adequately eliminated. The original drive shaft was mounted in a special frame underneath the typewriter. An attempt was made to silence the operation by cutting the intermediate spur gear from a hard-woven material impregnated with a resinous plastic and cutting the chain sprockets from vulcanized fibre. The result was only partially successful.

Further analysis led to a basic revision of the drives and layout in which the electric motor was re-located from underneath to the side of the typewriter and equipped with a worm-gear transmission drive as shown in Fig. 2. The requisite speed reduction of 15 is obtained by the steel worm through a raw-hide worm gear wheel, which is keyed to the typewriter drive shaft. The bookkeeping machine drive shaft is driven by a raw-hide intermediate gear wheel from the typewriter drive shaft. This redesign silenced the machines.

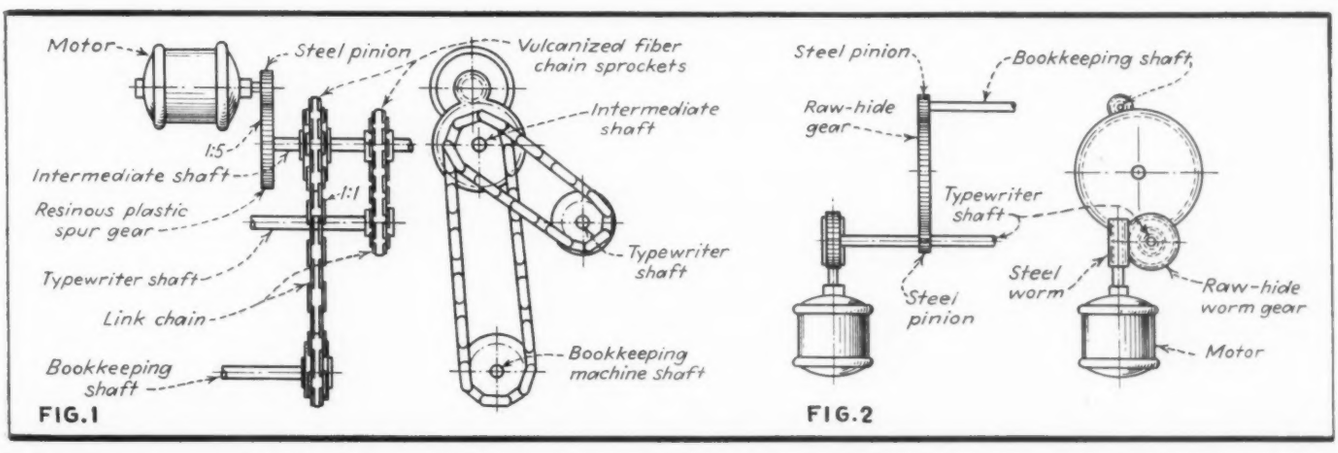
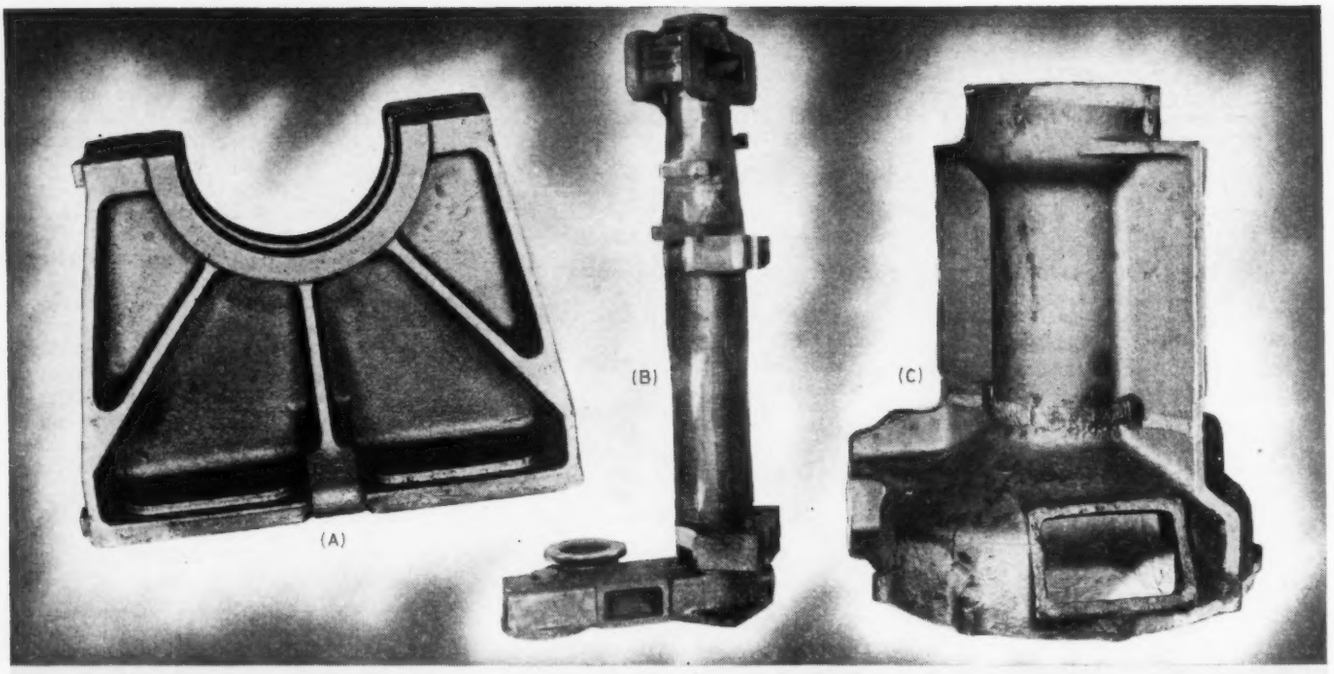


Fig. 1—Typewriter and bookkeeping machine with noisy power transmission. Fig. 2—Redesign for quiet power transmission.



(A) The small bearing stand can be made by welding or as a casting. An analysis of the piece indicated that a casting was not only easier to make, but better suited to existing plant facilities. The casting was also desirable as it helped to balance the work load between the foundry and welding shop.

(B) This large, complex bracket was first designed as a one-piece casting. Casting difficulties required changing to a weldment made up of three simplified castings. When a production line was established, still another change in design was made to permit the center section being made of carbon steel tubing.

(C) A composite structure on which the designer and welding engineer collaborated, the design being such that the main weld is freely accessible to the welder. By such collaboration, the designer can be certain that the structure he has placed on paper can be made in the shop with a minimum of effort.

Design of Welded Parts

RICHARD J. WOLF and CHARLES EIWEN
Navy Department, Washington, D. C.

Fundamentals of welding design and procedure for incorporating cast, forged and rolled sections into composite structures. Rules for good welding design and comparative data on strength of weld and base metals are given and typical welded parts are illustrated.

IN CREATING a new product the design engineer has three major factors to consider —utility of product, cost of manufacture, and the materials and methods of manufacture that are best suited to existing plant facilities. Utility cannot be sacrificed, but the individual parts can frequently be changed or modified to simplify manufacture or to fit existing plant facilities better. While considering these last two factors, the planning and production engineering staffs and the personnel of the manufacturing departments should be called in for consultation. Their recommendations can be of inestimable value and should be incorporated wherever possible, preferably before the design is stabalized for production.

The production of a pilot model, where the quantities justify the cost, is another check on the manufacturing problems. Its use is strongly recommended. Foremost in the designer's mind should prevail the principle that changes can be made cheaper on the drawing board than in the shop.

A purpose of this article is to furnish the designer with an outline of the DO'S and DON'T'S in the design of welded composite structures. The more thoroughly these DO'S and DON'T'S are applied in the original design the less the product will cost, the fewer will be the changes during manufacture, and the quicker will the product go into production. The designer has his reward also. He will be requested to make fewer changes; his work will be speeded and simplified.

The following lists good welding design

practices to be considered in the design of composite structures. The rules apply to all materials whether castings, forgings, or rolled sections of steel, bronze, or aluminum.

Welding Design Do's

1. Locate joints so that they will be readily accessible to the welder.
2. Design joints so that a minimum of machining will be required in the joint preparation.
3. Use through welds in preference to fillet welds for welding stiffeners in restrained locations.
4. To avoid corner cracks and improve weldability, use relief holes at the right-angled junction of through plates.
5. Use high alloy, high strength, or corrosion resisting materials only where required.
6. Make changes which will facilitate manufacture.
7. Put on the drawings welding symbols that adequately describe the type of joint desired. The AWS system is recommended.
8. Know the efficiencies that can be expected from welded joints and the types of joints that will provide acceptable strength most efficiently.
9. Design welding grooves for welding conditions as well as for the required strength.
10. Through cooperative effort, establish a welding procedure for the shop and furnish those details on the drawing.
11. In critical locations on heavy weldments where through welds are used and restraint may be great, make provision for inspection of the root chip. On steel structures the magnetic powder method is generally an effective inspection method.
12. Proper application of materials (castings, forgings, or rolled sections) will reduce the machining required on the final product.
13. The use of standard of special rolled sections frequently offers opportunities to effect substantial reductions in over-all costs.
14. Good inspection improves the quality of welding performed in a shop. Specify on the drawing the type of inspection desired, including an inspection of the fit-up of the work prior to welding.
15. Where dimensional stability is required and stress-relieving or other stabilizing treatment is essential, it should be specified on the drawing.
16. Machinability of steel structures is improved by stress-relieving.

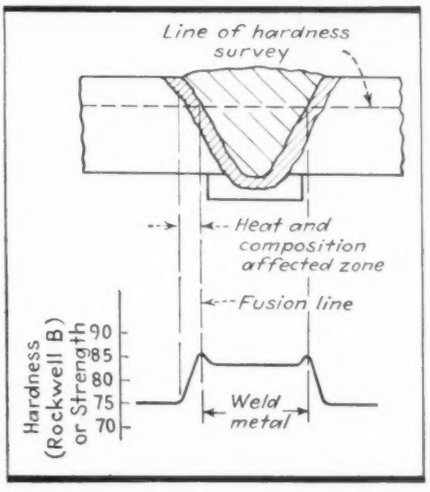


Fig. 1—Sketch showing variations in hardness and tensile strength of the metal in the welded joint.

Welding Design Don'ts

1. Don't use specifications which are more rigid than necessary to accomplish the desired results.
2. Don't overweld—not only are time and material wasted, but warpage and stresses are greater and appearance is usually not as good.
3. Don't freeze a design until the production department has a chance to analyze it. In this respect, a pilot piece will provide a positive check of a design.
4. Don't think costs are not a responsibility of the designer.
5. Don't try to produce designs which are a challenge to the manufacturing departments. Cooperate to make their job easier.

Variations in hardness and tensile strength across a welded joint are illustrated in Fig. 1. Table I contains block charts giving the designer an idea of the strength of weld metal compared to that of plate or sheet. The base materials shown are among those commonly employed in welded structures, and the corresponding welding electrodes are those recommended for use with the material. While the block diagrams provide a ready means of comparison, it should be understood that other physical properties, such as impact strength, fatigue strength, and ductility are not to be overlooked. Furthermore, the effect of the welding operation on the base material must also be considered.

Table I — Comparison of Weld and Base Metal Strengths

Plate	Yield Strength, lb. per sq. in.		Welding Electrode	Plate	Tensile Strength, lb. per sq. in.		Welding Electrode
Carbon Steel Plate — ASTM A78	27,000	52,000	AWS E6010, E6020 or E6030	Chromium Nickel Steel Plate (Soft) — ASTM A167 Types 301, 302, 304	75,000	80,000	18–8 Cr-Ni (Navy Gr. I-1 (46-E-4))
Carbon Silicon Steel Plate — ASTM A201	35,000	52,000	AWS E6010, E6020, or E6030	Chromium Nickel Steel Sheet (¼ Hard) — ASTM A177	125,000	80,000	18–8 Cr-Ni (Navy Gr. I-1 (46-E-4))
Manganese Vanadium Steel Plate — ASTM A225	43,000	52,000	AWS E6010, E6020, or E6030	Aluminum Plate (AL-2) (Soft) ASTM B178	11,000	12,000	AWS AL-2
Structural Nickel Steel — ASTM A8*	55,000	57,000	AWS E7010, E7020, or E7030	Aluminum Alloy Sheet (Annealed) — ASTM B109	34,000	14,000	AWS AL-43
Carbon Steel Castings ASTM A215	35,000	52,000	AWS E6010, E6020, or E6030	Phosphor Bronze Sheet (Soft) ASTM B103 Grades A and B	40,000	35,000	AWS ECu-Sn
				Phosphor Bronze Sheet (Soft) ASTM B103 Grade D	58,000	35,000	AWS ECu-Sn
				Brass Sheet (¼ Hard) ASTM B36 No. 6**	49,000	25,000	AWS ECu-Sn

* Structural nickel steel is not a weldable steel, but under controlled welding conditions, it is possible to weld this material in such fashion that the composite structure has physical properties equivalent to those of the base material.

** Brass is welded with several electrodes and rods, and the desirability of one material over another is dependent on many factors including equipment, operator skill, and end use. The method suggested of arc welding with phosphor bronze electrode is not the most desirable method in all cases.

Machine Design Textbooks Should Contain What Name Implies

ZOLA FOX
Design Engineer, Sperry Gyroscope Company, Inc.

A plea for the inclusion of more detailed and specific engineering data in machine design textbooks. An experienced engineer looks back at the obvious shortcomings in the information he obtained from college textbooks, and presents some suggestions for their improvement in teaching design engineering practice to student engineers.

WITH THE new design data now available after World War II, there is no doubt that many new books on the subject of machine design will be written and present editions revised. It seems a proper time, therefore, to discuss what the author feels are prime failings in many currently available books on machine design.

During the last two decades the general trend taken by writers of books on machine design, suitable for use by senior college students and practicing engineers, has been to depart from so called "empirical" design and tend toward "analytic" design. This trend is justified and is consistent with the continued refinement of machinery in general, which has resulted from present day demands for high speeds, light weights, high production, high stresses and low costs.

Unfortunately though, machine design books are becoming primarily books on advanced applied mechanics with occasionally a sprinkling of meager design information. In going from empiricism to analytics, writers have confounded "good practice," of which knowledge is essential in all design, with "empiricism" to the extent that far too little emphasis on "good practice" is given. There are sincere attempts to illustrate "good practice." But what is often evident by examination of machine design books is the paradox of illustrating and supplementing the latest in analytic and refined machine design, by means of designs and empirical formulas that have the feel of the steam shovel machine age.

Also omitted to a large extent is what is now called "Detail Design"; little tips and tricks on what types of screws may be applicable in tight corners; information on uncommonly used yet readily available standard parts suitable for solving the more or less classical design problems. The problems a designer meets are not all of the type that can be solved by mathematical calculations and the knowledge of formulas. Not by far! And let it be clearly understood that the author does not feel that any of the analytic information now in machine design books should be omitted.

Primarily it is not what is wrong with the material in current machine design books, but what they lack both in emphasis and subject matter. An example that typifies the academic attitude, and improper presentation that pervades, is the usual comprehensive discourse on stress concentration with little emphasis on the fact that in industry these factors are applied only to designs in which there is repeated stress or the members are made of brittle material.

The desirability of utilizing in design the existing standard parts, of all types from turnbuckles to spherically seated washers, should be clearly presented. But not in the tabulated fashion of handbooks, which soon become outdated. It is more important for the student to know the different types of common lock nuts, for example, by name and application, than for him to have detailed dimensional data on a few types.

The engineering graduate entering industry looks upon his machine design book as a bible to furnish him with guidance and information on his first design problems. He is in competition mainly with high school graduates having perhaps several years of layout experience who do not know much about analytic mechanics, but who by practice and observation are familiar with fitting things together and using standard parts in ways that are recognized as "good practice."

DETAIL DESIGN. Recently some colleges have introduced courses in "Detail Design." To illustrate what the author means by detail design information, consider the following items that are omitted in many machine design books and that a recently graduated engineer, working perhaps on his first major layout or design job, has to know where to find to make a "showing" at his new job:

1. Rationalization of fits, tolerances and workmanship obtainable by different machine tools and manufacturing processes.

2. Typical values of fits to be used; how fits may differ when used for similar applications but by different industries.

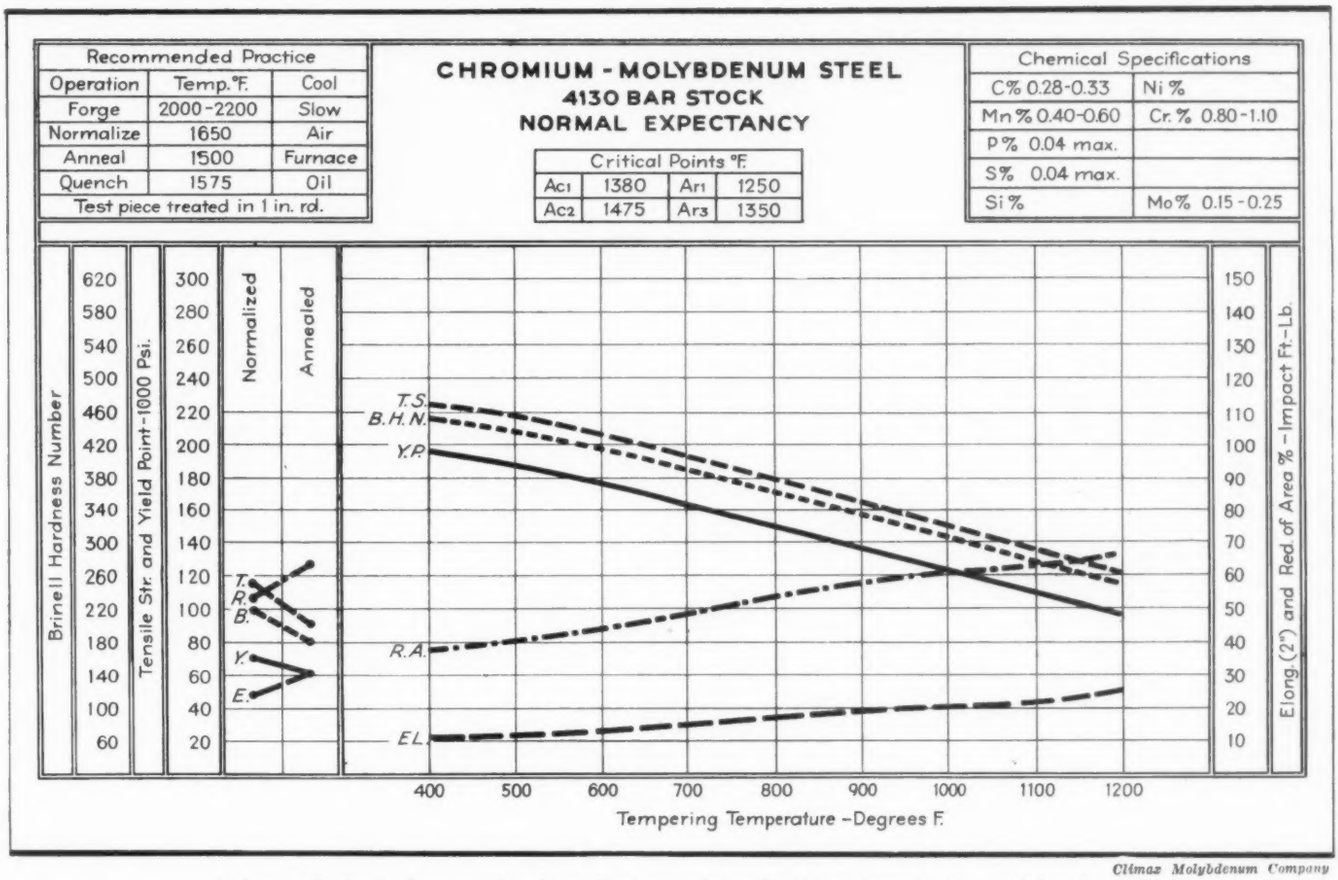
3. Minimum bend radii on sheet metal parts. Minimum fillet radii on cast or forged parts for different materials. Minimum section thickness of forged or cast parts for different materials. Draft angles on forged and cast parts.

4. Materials applicable in different industries for various applications, with indication of heat-treatment and types of finish suitable.

5. More complete tabulations of properties of engineering materials than are commonly available. Physical property tables should clearly indicate the test specimen's heat-treatment or hardness and size. Widely used standard material specifications such as the S.A.E. or A.I.S.I. should be chosen. Physical property charts of the types usually found in the older S.A.E. Handbooks are really usable. Generalized physical property tabulations for heat-treatable materials, covering typical properties and average ranges of physical properties without hardness and size included, are relatively insignificant and do not indicate suitability for particular applications.

Much of the information previously stated may be said to belong properly in books on shop practice or drafting. Examination of current industrial procedures, however, will reveal that engineering departments are shouldering more and more responsibility in supervising design, manufacturing and purchasing. Drawings contain nowadays much more information than they did a decade ago. The machinist or mechanic is instructed to make and assemble exactly what is on the drawing and to follow procedures planned out previously in detail by engineering. Nothing is left to his discretion. Deviations that are permitted must fall within previously prescribed tolerance boundaries.

This practice is necessary for quality control and interchangeability; both being prerequisites to high production and dependable performance. For example, whereas fillet



Climax Molybdenum Company

A form of physical property chart that correlates heat-treatment, size and hardness.

radii and draft angles on castings were often left to the discretion of pattern makers they are now generally specified by engineering. Direction of grain and surface finish in microinches are often specified. Tolerances are even specified on common chamfers. The junior design engineer must have such information at his fingertips and though standard practices vary from company to company they are not far apart. Information of this type belongs in machine design books.

POOR, GOOD, AND PREFERRED DESIGN. Another shortcoming in machine design books is that the reader is not advised on the choice of one or more methods of designing a particular part, with poor, good and preferred designs indicated. Specific data occasionally is lacking that would govern proper choice of design. For example, most books blandly mention that there are fine and coarse threads. Seldom is it mentioned how much stronger fine threads may be than coarse, or that one is more preferable than the other when vibration is present and the other more preferable when there is possibility of corrosion or frequent disassembly is anticipated. It is indeed surprising that such basic omissions are made in spite of the fact that data have been available for years.

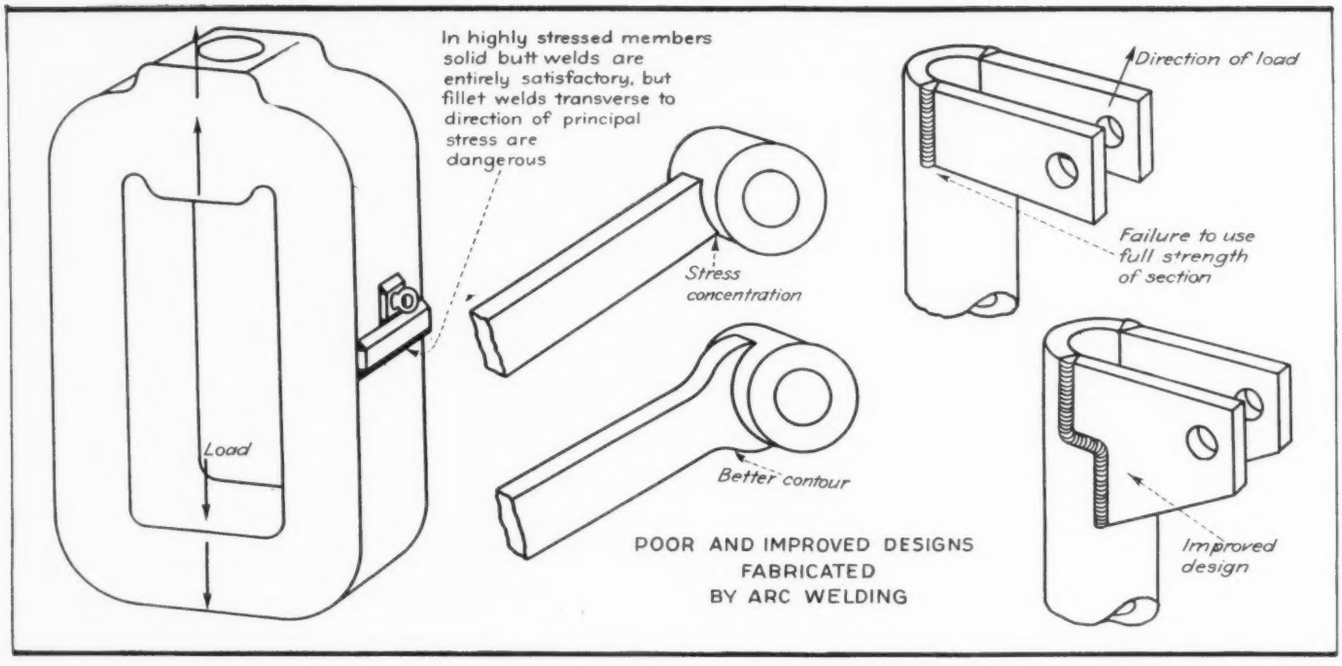
The antiquity of data furnished, and their inapplicability to the topic discussed, that are found is surprising. A recent design book on aircraft engines in its discussion on the strength of studs quotes an old table on the strength of coarse thread bolts as indicative of the strength of aircraft studs. A "fudge factor" for vaguely defined differences in material and application is also included. Writers of machine design books should furnish information that is not only applicable and as complete as possible, but they should try to include the latest possible information.

MATERIALS. The chapters on materials in machine design books are often of little practical use to the young machine designer. An older, more experienced man knows the various trade publications and catalogues that would have the exact information he wants, but the inexperienced designer would prefer to rely on books more familiar to him. Chapters on materials lack complete information on really important materials and are misleading because of improper or incorrect emphasis placed on relatively unimportant materials.

Much space is usually devoted to the effect of alloying elements on various metals and tabulations of the physical properties of different materials. These physical property tables are generally useless because the heat-treatment and hardness are often not included. What is lacking and really needed are physical property charts, not tabulations of the more commonly used materials. There really aren't many necessary, as all do not have to be covered, and their inclusion in books would not take up much space. For example, some of the most commonly used steels that find wide application because of variable properties obtainable by heat-treatment are 1025, 1045, 4130, 2330 and 3325, five in all.

Also valuable, is information on composition and strength, for different tempers, of loosely defined and yet so widely used materials as cold rolled steel, strip and bar, and drill rod. These should be given, but seldom are. More complete information on stainless steels and more emphasis on the variable properties of common materials with heat-treatment should be presented. Properties obtainable by surface treatment such as carburization, nitriding and shot blasting should be discussed in detail in connection with proper application.

After all, the more common engineering materials are the backbone, the building blocks of machinery and detailed information pertinent for machine design should not be left for the student to find in so-called handbooks. Materials should be defined and referred to by the society designation most commonly used by industry as well as their primary chemical constituents. Whenever materials of special composition are mentioned, or tabulated, the trade names by


In highly stressed members solid butt welds are entirely satisfactory, but fillet welds transverse to direction of principal stress are dangerous
Load
Stress concentration
Better contour
Direction of load
Failure to use full strength of section
Improved design
POOR AND IMPROVED DESIGNS FABRICATED BY ARC WELDING

The Hobart Brothers Company

which they are known should also be given.

Notably worthwhile inclusion in material chapters are tabulations of representative materials used in typical applications with their respective heat and surface treatments. For example, in typifying material selection practice, three common machines from widely different fields can be selected; say a steam shovel, a drill press and an aircraft engine. Complete tabulations of representative materials and finishes used in the principal parts of these machines will be more of a guide to judicious choice by a novice designer than any other written matter in the book.

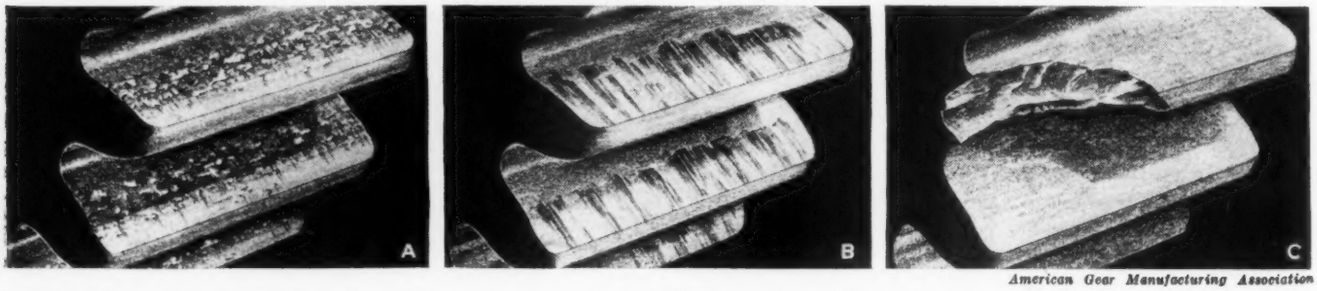
Fits and Tolerances. The typical material application tabulations as discussed under "Materials" can serve as a pattern for another use. That is in the selection of fits and tolerances. To a beginner the A.S.A. fit classifications so often repeated are not a sufficient guide to the selection, with confidence, of specific clearances and tolerances.

Tabulations showing how fits may differ from one industry to another even though the basic application may be the same are worthwhile. This not only supplies the reader with information on "good practice" in general, but emphasizes the influence the function the machine has to perform on the detail design of its components. For example, a bearing in a steam shovel and a bearing in an aircraft engine, though say subjected to the same nominal load would be as much alike as night and day. Typical pilot, force, shrink, stud, bearing, sliding fits should be given for similar applications, but different fields.

Tolerances obtainable by different production processes influence to a considerable extent the detail design and comprehension of the overall machine picture. Applicable tolerances on common machine components should be given. Tables of tolerance ranges obtainable by different machine tools and production processes, such as Table I, should be prepared and included.

Sheet Metal Practice. The omission of sheet metal practice from machine design books emphasizes the tendency away from inclusion of practical design data. Sheet metal components have had and are finding increasing application. Basic data such as bend radius, bend allowance, spotweld, riveting, drawing and spinning information and influence of grain direction should all have the deserved part their widespread applications to machinery entitles them to have. Furthermore, the advanced methods of sheet metal structural design as refined and developed in aircraft practice are bound to be applied to machinery and merit special consideration.

Welding. The outstanding omissions in chapters on welding as presented in machine design books are information on brazing and spot welding. Data on the strength of spot welding as a function of spot diameter, spacing, material thickness and so forth have long been available and should be given, preferably in the form of curves. A wealth of new data pertinent to brazing, such as recommended fits, materials, and designs are available. The role brazing is playing in machine design can no longer be skipped



American Gear Manufacturing Association

Modes of gear failure and how they differ in appearance. (A) Progressive pitting is indicated when the formation of pits continues at an increasing rate, both in number and size. (B) Scoring results from excessive loading or inadequate lubrication. (C) Fatigue breakage results from repeated loading and is usually characterized by the formation of cracks at highly stressed locations.

over lightly. The methods of using standard shapes in welded construction such as tubing, angles, plate and so forth should be carefully explained and amply illustrated.

MACHINE PART FAILURES AND CAUSES. A shortcoming of college texts and courses on machine design in general, is the rather complete omission of descriptions, photographs and analyses of the types of overall machine and component part failures that occur as a result of improper design or of other causes. The engineer is not in industry very long before he sees machinery, which he has designed, disassembled after continued operation. Generally, he depends considerably on the frequently unreliable analysis of mechanical performance made by a mechanic or operating engineer who, with all due respect, often has many unfounded prejudices and ideas on the modes of failure.

A chapter on gearing in a machine design book, for example, should illustrate the difference in appearance of the teeth of a gear set that is failing from pitting as a result of surface fatigue failure and the appearance of the gear teeth when scoring from perhaps lack of lubrication. Many young designers, simply because they have never seen it before, are frightened while witnessing the first disassembly of a machine they have designed by the presence of brown oil varnish on or near bearings. Galling is likewise a mystery.

The structure of fractures of simple test specimens as usually observed in laboratory tests are suitable only in a general way for assisting in the analysis of a machine failure. The appearance of the fractured section of a part is often the only way to trace the failure of a machine from mating part to mating part until the initial cause or the starting point of the failure is found.

The author recently had an experience that is indicative of how little the causes of machine part failures other than those resulting from insufficient strength are impressed upon students of machine design. An earnest young engineer showed to the author an unsuccessful experimental clutch designed for an aircraft instrument. The clutch had repeatedly failed in test under conditions not nearly as severe as it would be subjected to in service. Several redesigns had been made but each performed equally bad. A brass gear, which was intended to idle on a steel shaft at certain periods, persistently seized on its shaft and galled on its shoulder in every test.

After discussing the problem, it was obvious that the materials would have to be changed and the parts redesigned to permit a greater rate of heat dissipation. When the engineer was told that the basic cause of failure was excessive temperature, he could not understand how it was possible for the gear to seize on the shaft as brass had a higher coefficient of expansion than steel and therefore the higher temperature would open rather than close in the clearances.

The engineer had never been told before, or had ever seen in any of his text books, that seizure in bearing failures results from excessive local temperatures and is often manifested by a form of welding, even if the mating materials have widely different melting points. The material with the lower melting point melts first and then may "wet" the other material.

Table I—Tolerances Readily Maintained on Common Machine Tools

All are total tolerances in inches

Automatic Screw Machines	
Outside dia	0.003
Pitch dia	0.002
Drilling	
Drill sizes No. 60 to No. 30	0.002
Drill sizes No. 30 to No. 1	0.003
Drill sizes 0.25 to 0.50 in	0.004
Drill sizes 0.50 to 0.75 in	0.005
Drill sizes 0.75 to 1.00 in	0.007
Forming with Lathe Form Tool	
Width less than 3/4 in	0.003
Width 0.75 to 1.50 in	0.004
Reaming	
Holes less than 0.50 in. dia	0.001
Holes 0.50 to 1.00 in. dia	0.0015
Holes 1.00 in. and larger	0.002
Power Milling	
Depths	0.002 to 0.003
Milled Slots	
Widths 0.25 to 0.50 in	0.004
Widths 0.50 to 0.75 in	0.006
Widths 0.75 to 1.00 in	0.008
Lathe, Rough Turn	
Diameters 0.25 to 0.50 in	0.005
Diameters 0.50 to 1.00 in	0.007
Diameters 1.00 in. and up	0.015
Lathe, Finish Turn	
Diameters 0.25 to 0.50 in	0.002
Diameters 0.50 to 1.00 in	0.003
Diameters 1.00 to 2.00 in	0.005
Diameters 2.00 in. and up	0.007
Lathe, Boring	
Rough	0.008
Finish	0.005

PRINCIPLE OF OVERSIZE BOOKS. Some may be inclined to say that if all data of the type discussed were conscientiously added in their proper places to books on machine design, that the size of the book would be increased considerably. Furthermore, it may be said that this would have many disadvantages from the text book point of view. Instructors would certainly be unable to cover the entire book in the time normally allotted and the sale of the books would be hampered by a higher price. This is a short sighted attitude. Knowledge is living, not dead. As long as knowledge lives, it grows. Whereas a few hundred years ago a library consisting of a book on mathematics, one on phsyics and one on chemistry would probably cover the entire realm of scientific engineering intelligence, today the case is far different.

The author in his practical experience has received much help from what he calls "oversize books," text books that were only about half read in college, the unread portion being "too advanced" for the class, but certainly usable in practice. Because the book was available and familiar, it was not only convenient to use, but more understandable than handbooks with different terminology and strange symbols. Students of engineering invariably retain their college text books as their bibles of information. They use these books not only for reminders of the learning they have forgotten but also as a source for more details.

In the past, the classical so-called hand books have been the principal fund of data on "good practice," from which writers of machine design books have freely drawn. Perhaps a more proper approach would be to classify and select more appropriate material than has been done previously out of the design standards of private industry. The general pattern of design standards as established by the Army-Navy-Civil Committee on Aircraft Design Criteria (ex. ANC-5) may well serve as a guide to the presentation of design requirements. Periodicals and manufacturers' catalogues, in particular, for the last few years are chock-full of the very type of detail design data that the old machine design books and handbooks do not contain. Let the new books on machine design really contain what their name implies and not just an introduction to the subject.

AUTOMATIC CONTROLLING MECHANISMS

In addition to the pressure-operated valve controllers presented in the June issue, other types, utilizing electricity for their actuation are available. These may be used to control valves individually or in gangs, and provisions for manual control are often included. Some of these are described and illustrated below.

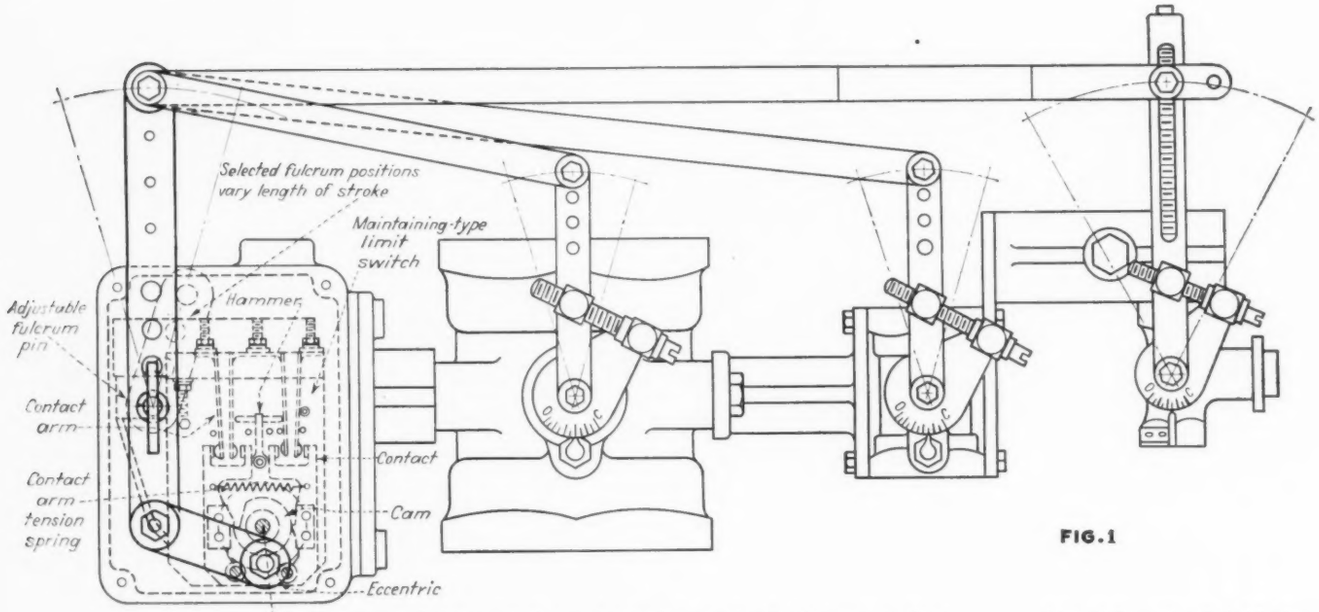
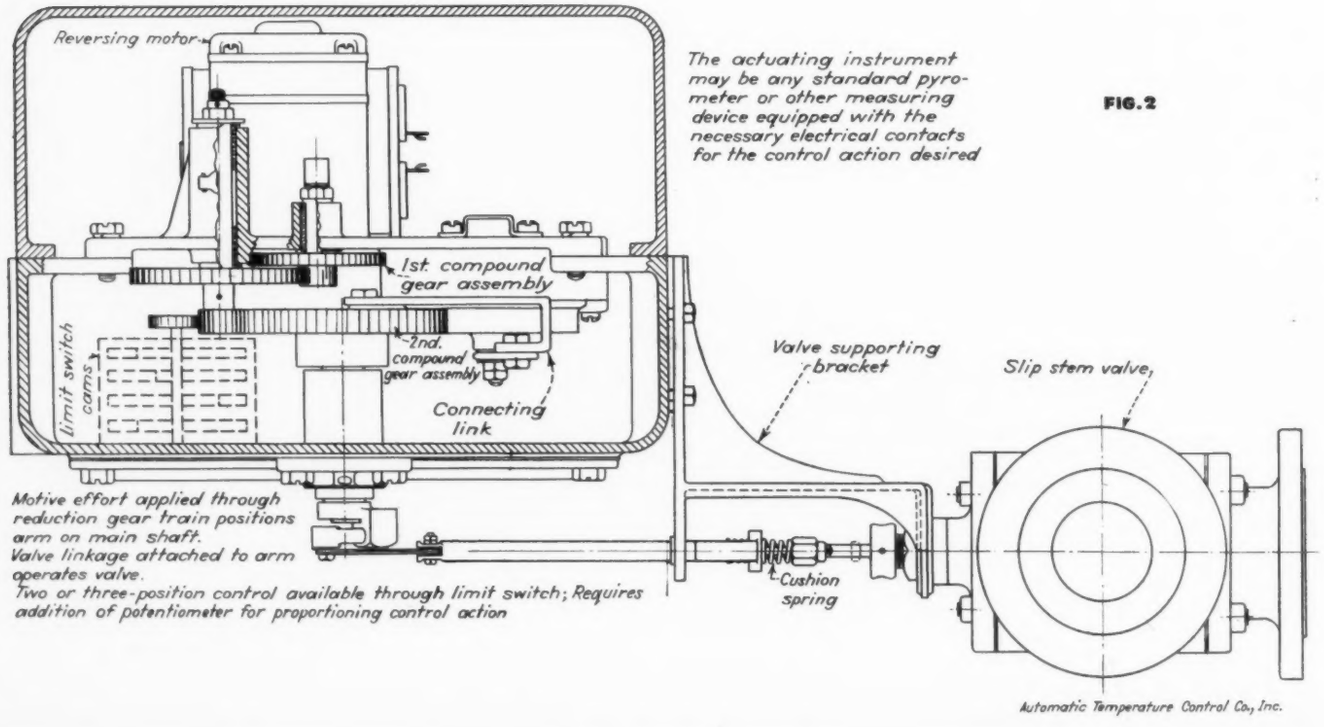


FIG. 1

Input from uni-directional motor and reduction gearing to give reciprocating controlled movement to valve assembly by use of eccentric

Automatic Temperature Control Co., Inc.



The actuating instrument may be any standard pyrometer or other measuring device equipped with the necessary electrical contacts for the control action desired

FIG. 2

Motive effort applied through reduction gear train positions arm on main shaft. Valve linkage attached to arm operates valve. Two or three-position control available through limit switch; Requires addition of potentiometer for proportioning control action

Automatic Temperature Control Co., Inc.

FOR VALVE OPERATION—II

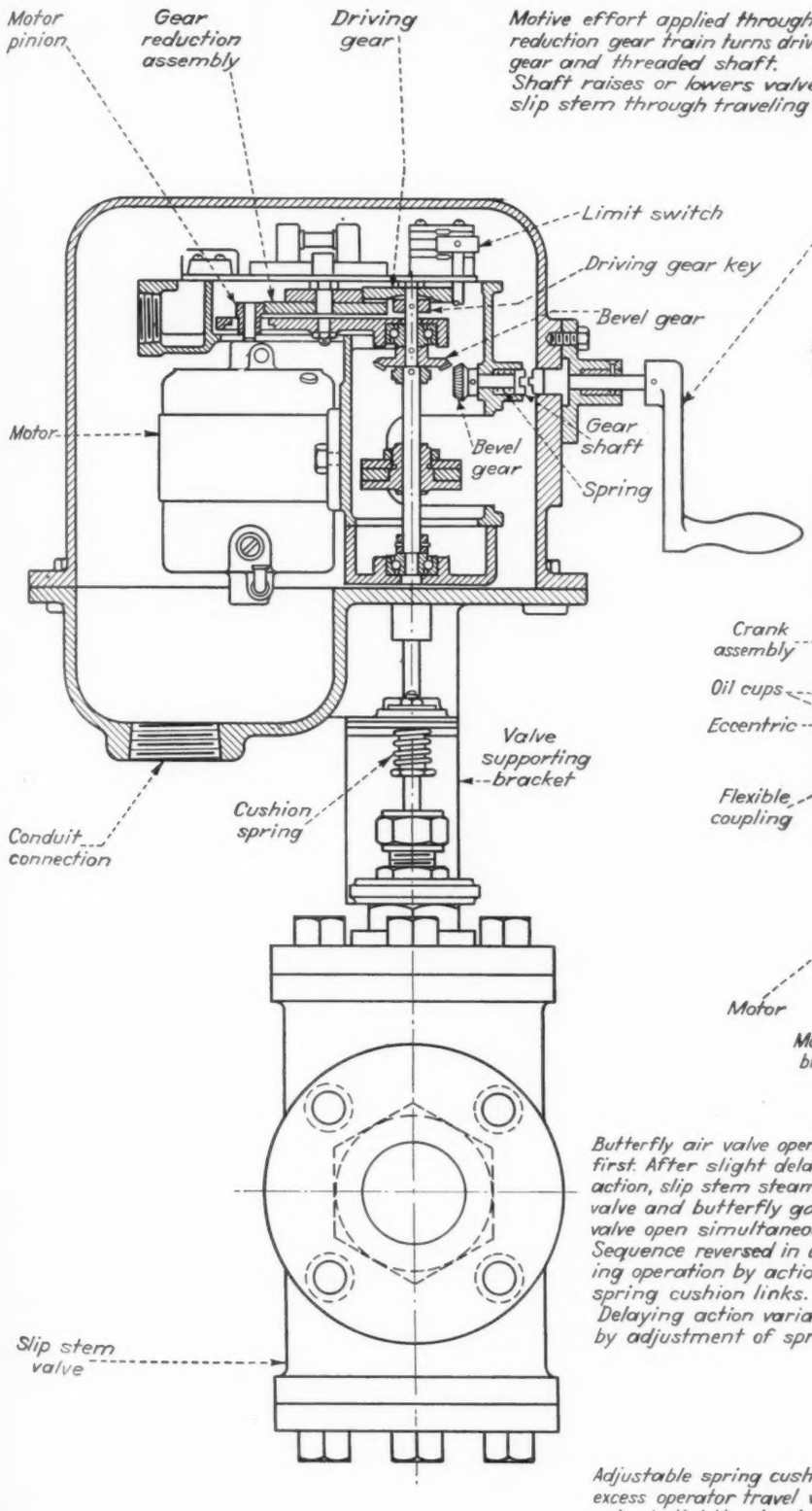

Motor pinion
Gear reduction assembly
Driving gear
Motive effort applied through reduction gear train turns driving gear and threaded shaft. Shaft raises or lowers valve slip stem through traveling nut
Handcrank for manually positioning valve in event of power failure
Limit switch
Driving gear key
Bevel gear
Motor
Bevel gear
Gear shaft
Spring
Valve supporting bracket
Cushion spring
Conduit connection
Slip stem valve
Butterfly air valve opens first. After slight delaying action, slip stem steam valve and butterfly gas valve open simultaneously. Sequence reversed in closing operation by action of spring cushion links. Delaying action variable by adjustment of spring

FIG. 3

Automatic Temperature Control Co., Inc.

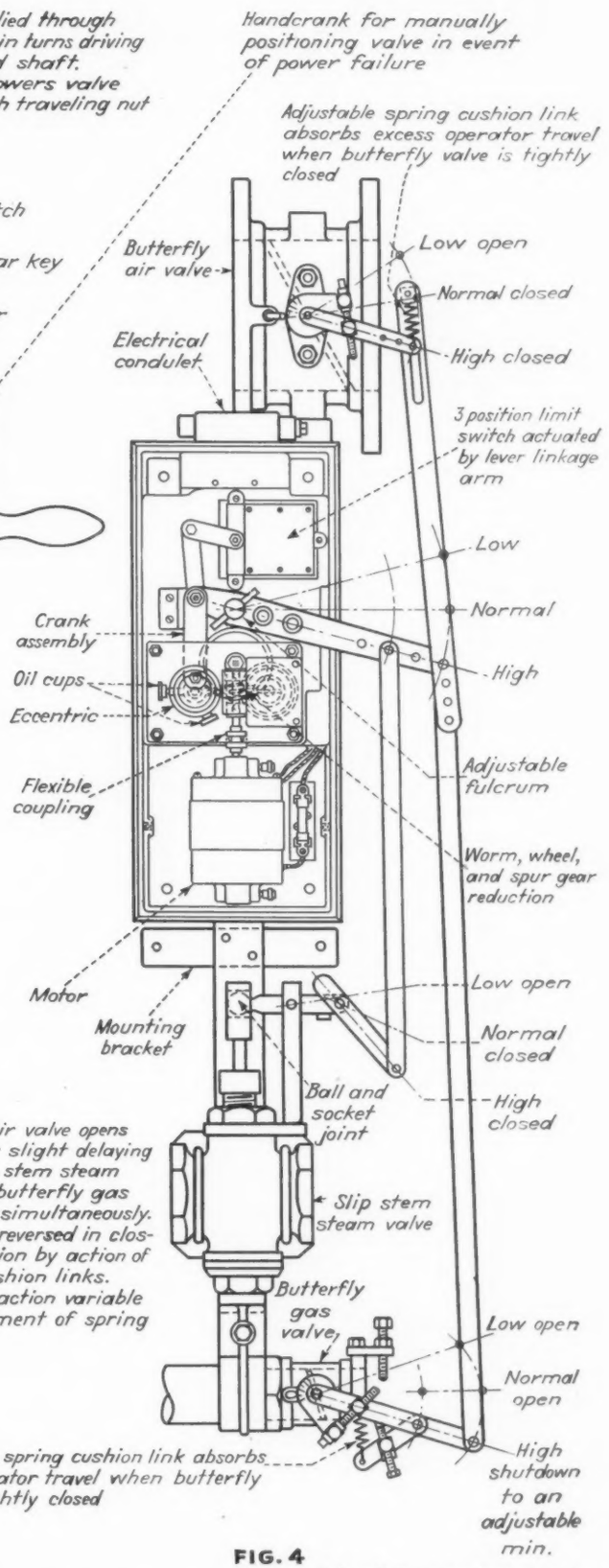


FIG. 4

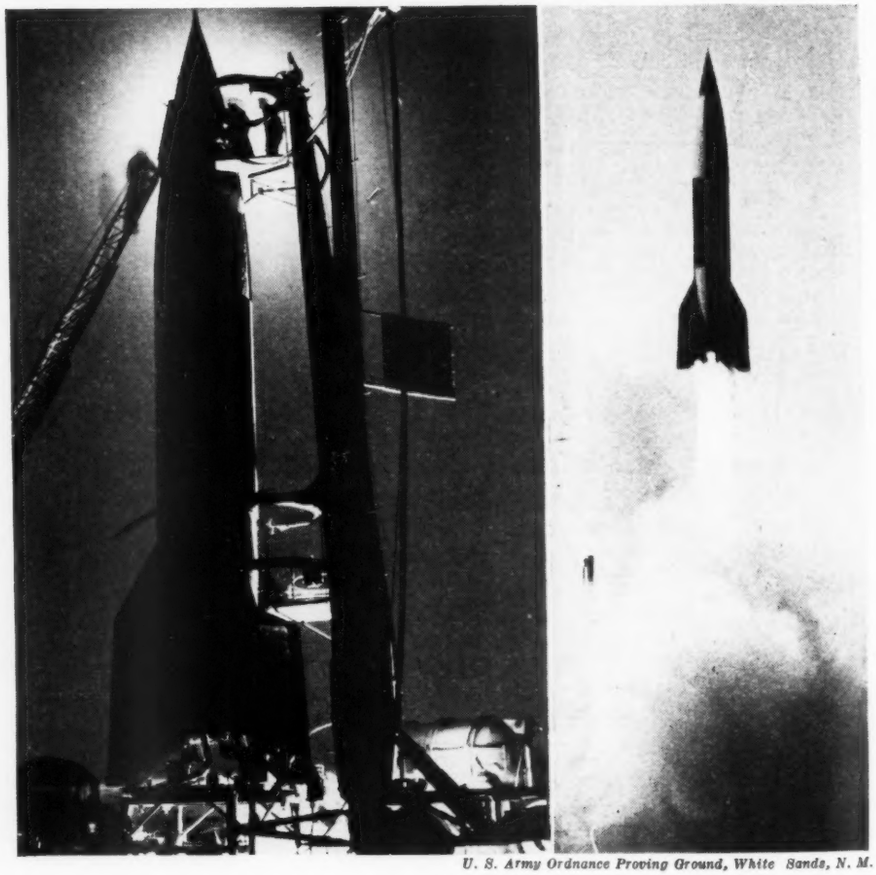
Automatic Temperature Control Co., Inc.

INDUSTRY AND SOCIETIES

RESEARCH—STANDARDS—PATENTS

ROCKETS

Long considered impractical missiles of the Buck Rogers variety, rockets are coming into their own as a result of war research. Tests now being conducted by the Army at White Sands Proving Grounds show that these war weapons have technical implications for the future. The German V-2 rocket, shown at right being prepared for launching and just after taking off, is the star of the show. Experimental firings promise not only to develop better rocket design, but also to obtain fundamental information about the nature of the upper atmosphere.



U. S. Army Ordnance Proving Ground, White Sands, N. M.

SPECTACULAR FIRING of V-2 rockets at White Sands, New Mexico, begun on May 10, will be continued at the rate of one a week for a minimum of 25 weeks. Assembled from captured V-2 rocket parts by German scientists brought here especially for the purpose, these rockets will help us obtain fundamental information to develop more efficient, longer-range missiles.

Besides the Army Ordnance Department, in charge of the V-2 test program, there are associated: The Army Signal Corps, who are interested in the physics of the upper atmosphere and are supplying electronic tracking apparatus; the Army Air Forces, who look upon the V-2 rockets as "pilotless aircraft"; and the General Electric Company, which has a crew of technicians and scientists at White Sands to help assemble the V-2's to replace missing parts and repair damaged ones, and to design test stands and electronic controls.

The V-2 will not be the only rocket fired at White Sands. Prominent in the program will be periodic launching of the "WAC" rockets, American missiles developed by Army Ordnance. These rockets operate on the same general principles as the V-2, but are smaller and lighter, and do not have the elaborate controls and range of the German rocket.

White Sands Tests

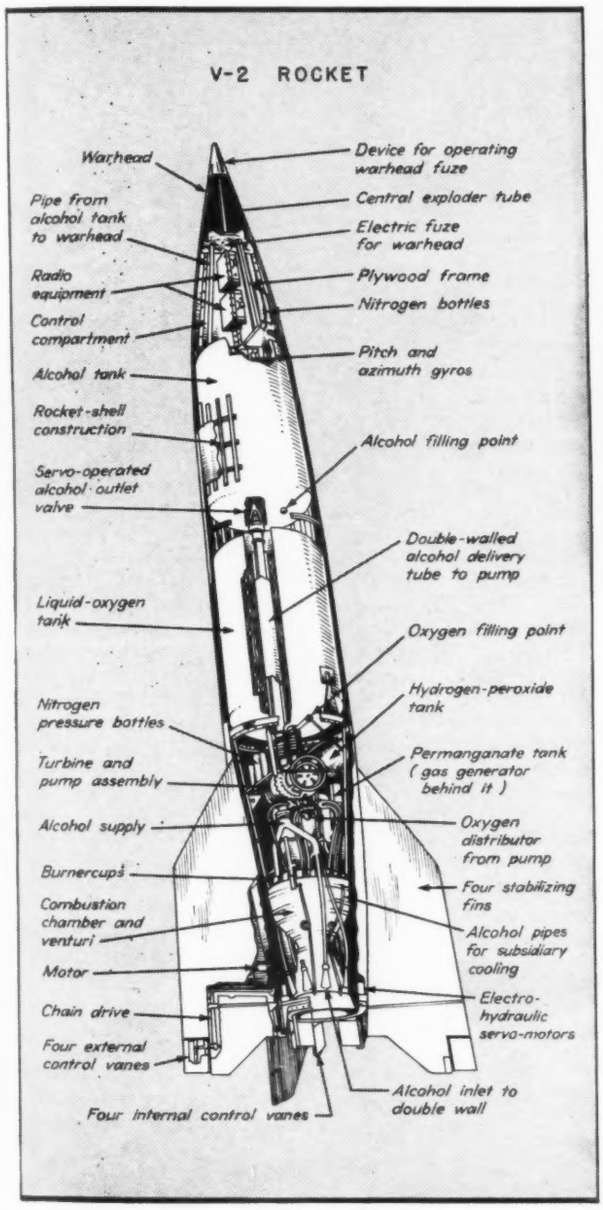
The physics of the upper atmosphere is expected to be probed at the White Sands tests. The V-2 rockets are expected to reach an unprecedented height of 120 miles before hitting the desert sands about 80 miles north of the firing platform.

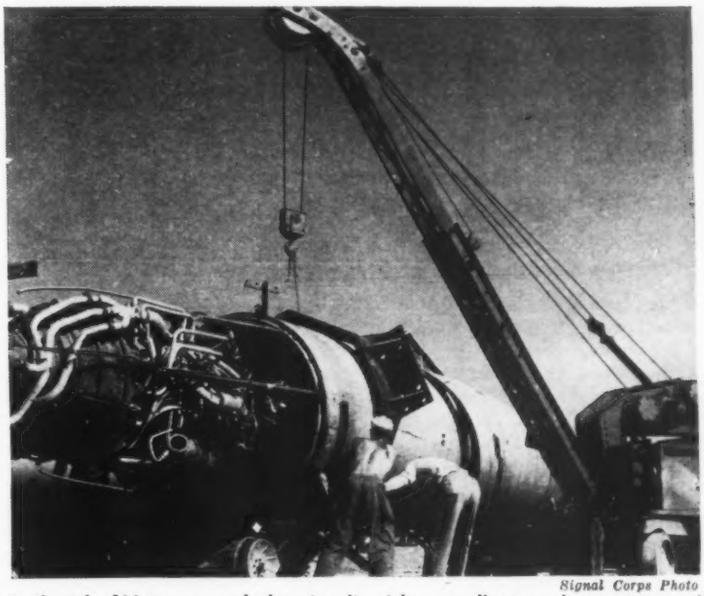
The Army Ground Force's new guided missiles unit, the 1st Anti-Aircraft Artillery Guided Missiles battalion, is performing its first mission in firing the V-2 rockets. A 9-man panel consisting of representatives of the General Electric Corporation, Princeton University, Harvard, Massachusetts Institute of Technology, University of Michigan, The Army Signal Corps, and the Applied Physics Laboratory at Johns Hopkins University has been organized under the direction of Dr. E. H. Krause of the Naval Research Laboratory to coordinate all scientific data on the physics of the upper atmosphere.

Rocket experts will trace the flight with the aid of a two-way radio, radar equipment, complete decontaminating equipment and air pressureizer and long-range telescope.

The rocket will be used to test the VT (proximity) fuze, telemetering equipment that furnishes data on pressures, temperatures, velocities and accelerations; control components that furnish roll and stabilization and fix the range and accuracy of the missiles.

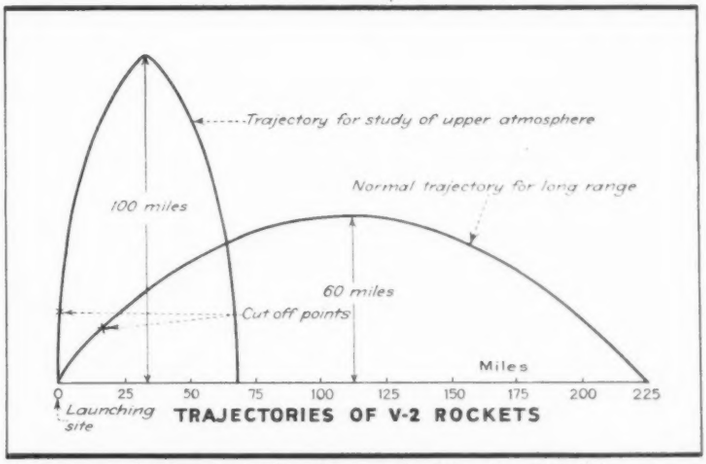
Seventeen checking stations are used in tracking the V-2. Four different tracking methods are in use: Radar, optical, photo,





Signal Corps Photo

Tail end of V-2 exposed, showing liquid-propellant rocket motor and fuel lines that carry liquid oxygen, alcohol and hydrogen peroxide.



Average height expected to be reached by the V-2 this summer is 100 miles, in a special trajectory designed for study of the upper atmosphere. Maximum height hoped for is 120 miles.

and sonic (Doppler). The radar methods involve impulses from a unit in the nose and reflections from three tail surfaces. Both optical and photo tracking are achieved with an ingenious German instrument, the Askino theodolite, set up 8 to 10 miles from the launching site. The unit has a tremendous lens, which enables two operators to watch the V-2 for 150 miles visually. A built-in camera records the action at 60 frames per second. Three of these instruments at widely separated points permit checking of "roll" of the projectile by showing the special pattern painted on it.

Newly developed radio beacons, which contain their own power supply and are actually miniature radio receiver-transmitters, have been fitted into the V-2, in place of the warhead, for one tracking device. Antennas are in plastic housings on fins. During flight, the receiver is triggered from a ground radar set by pulses that cause the transmitter to repeat the pulses to the radar. This permits the trajectory to be recorded photographically. The Signal Corps radar set used is modified from a unit developed during the war for detecting aircraft and directing antiaircraft guns. Conventional radar equipment also tracks the V-2 for its entire flight without the aid of beacons.

Upper Atmosphere Studies

The lack of elaborate control apparatus in the WAC rockets indicate that they will probably be used as a "sounding" rocket, to probe the upper atmosphere. Both the V-2 and the WAC (expected to reach a height of 80 miles) rockets will carry instruments to speed data back to earth.

Radar can track projectiles at supersonic speeds, and sections of a rocket can be detached by radio control to parachute instruments down. These include ozone analyzers and ionization meters that record data about cosmic and ultraviolet radiation. Special glass-lined chambers that open and reseal automatically have been built to bring back samples of the upper atmosphere. Some rockets also carry wide-angle infra-red cameras to photograph the earth from high altitudes.

Of greatest interest to scientists is the ionized atmospheric layer above the stratosphere, the ionosphere, which begins about 58 miles above the earth's surface. The sounding rockets should reveal much about the nature of the ionosphere as a shield protecting the earth from the intense bombardment from outer space. The filtering action of the ionized layers, on external radiation, is believed to be similar to that affecting radio waves from the earth. Cosmic rays,

which are believed to have some influence on life by disturbing hereditary factors in living organisms, penetrate certain layers and not others. Other phenomena to be investigated are "magnetic storms", temperatures at various atmospheric levels, radiation from atomic gases and gaseous structure of the atmosphere, to its outermost limits.

The V-2 Rocket

The German V-2 rocket represents the first successful attempt to build a large-scale projectile with a liquid propellant rocket motor. No doubt more efficient rockets, using different propellants and including many radical designs, will be built in the future. But the V-2 itself is a radical departure from conventional rocket thinking; it is for this reason that it is being studied at White Sands.

The main assemblies of the V-2, as used for military purposes, are:

1. Nose with 2,000-lb. explosive warhead.
2. Compartment with control equipment.
3. Two large aluminum fuel tanks, one holding about 7,500 lb. of alcohol and the other about 11,000 lb. of liquid oxygen.
4. Turbine and pump assembly with a gas generator to drive the turbine.
5. Large combustion chamber and venturi into which the alcohol and liquid oxygen are forced through a series of jets.
6. Two sets of control vanes. One set operates internally in the jet stream and the other externally on the edges of the four stabilizing fins.

V-2's Vital Statistics

Maximum range	230 mi.
Weight, unfueled	10,000 lb.
Weight, fueled	28,380 lb.
Weight of warhead	2,230 lb.
Alcohol	8,304 lb.
Oxygen (liquefied)	10,800 lb.
Overall length	46.05 ft.
Body diameter	5.41 ft.
Width across fins	11.69 ft.
Fuel capacity	2,500 gal.
Maximum velocity	5,600 ft. per sec. 3,800 m. p. h.

The rocket stands in a vertical position on a concrete platform or hard surface. The turbine, driven by gas generated from concentrated hydrogen peroxide mixed with a calcium permanganate solution, powers pumps that force the liquid oxygen and alcohol into the combustion chamber. This mixture is then ignited by remote electrical control, and the rocket takes off.

Once ignited, the mixture of oxygen and alcohol continues to burn violently. Combustion products are forced out at high speed through the orifice in the rear end of the venturi as a jet of very hot gas. The energy so liberated creates a thrust of about 26 tons, which propels the rocket.

The V-2 starts by climbing vertically, but a gyroscope control within the projectile automatically moves the control vanes, causing the unit to curve away from the vertical toward the target. The mechanism is so arranged that the rocket points upwards at an angle of 45 deg. about one minute after launching, and at this time the fuel supply is cut off either by remote control from the ground or by automatic instruments in the rocket.

The point at which fuel cuts off determines range. If fuel burns for a long time, high speed and long range result. If it burns for a shorter time, speed is less and range correspondingly decreases. Since the rocket points upward at 45 deg. when fuel cuts off and travels at about 3,000 m.p.h., it continues upward following the path that would be taken by a shell fired at this angle. There is a little air resistance in the upper regions and the rocket eventually reaches a height of over 60 miles above the earth's surface (for a normal trajectory) and comes down still following the parabolic path a shell would take.

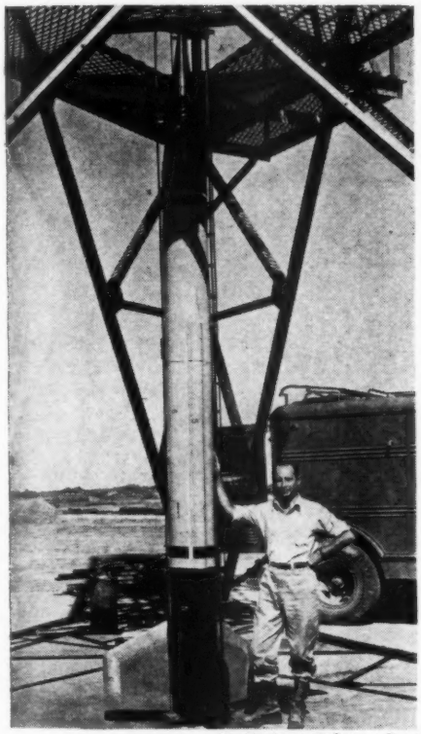
The WAC Corporal

American research in liquid-fuel rockets has resulted in the "WAC" series—WAC Private, WAC Corporal and WAC Sergeant rockets. Developed independently of the German V-2 rockets by the Army Ordnance Department and the California Institute of Technology, the WAC Corporal is the outstanding member of the series.

Unlike the V-2, the WAC Corporal has no control system except for three stabilizing fins. It is launched vertically from a triangular 100-ft. tower. It is boosted during the first moments of its flight by a solid-fuel step rocket. The latter is reported to be the "Tiny Tim" rocket, but this report has not been commented on by military authorities.

Elevating boom, designed in Germany, is known as the "Meiller Wagon". It carries the V-2 and sets the rocket in place by means of a motor-driven hydraulic system. The carrier-boom is equipped with platforms which enable workmen to climb up its ladders to make adjustments. Feed lines for fuels are built in.

German Kino Theodolite has a tremendous lens through which the V-2 can be seen visually for 150 miles. A built-in camera records the action at 60 frames per second. Three of these instruments at widely separated points permit checking of roll of the projectile by showing the special pattern painted on it.



U. S. Army Ordnance Dept.

"WAC Corporal" ready to go into launcher.

The step rocket brings the WAC to supersonic speed in 0.6 second, then falls away to let the liquid-fuel motor carry on alone.

The Corporal is 1 ft. in diameter, 16 ft. long, and weighs 700 lb. at launching; about half this weight is oxidizer and fuel. Its body is made of steel, aluminum and magnesium.

Although full technical details of the WAC have not been disclosed, it is known that its motor is basically similar to that of the V-2, except that the fuel and oxidizer used are different. Aniline is the fuel, and nitric acid is the oxidizer, analagous to the liquid oxygen in the V-2. This fuel was chosen because the WAC Corporal was originally intended for use as an antiaircraft rocket; it was felt that liquid oxygen would evaporate and thus would not be suitable for "sudden" firing, requiring advance setting.

An improved model of the WAC Corporal, to be known as the WAC Sergeant, is being built by Army Ordnance.

How Rockets Work

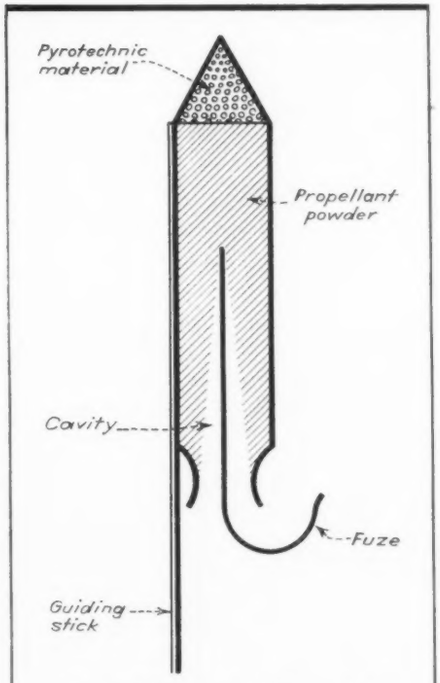
To people who have been bombarded throughout the war with Bazookas, mortars, Tiny Tims, Buzzbombs, Wac Corporals and V-2's, the word "rockets" must be, at the very least, confusing. Some of these weapons have erroneously been called rockets.

A rocket is a missile propelled by the high speed, rearward expulsion of gases generated by the combustion of an internally carried fuel. Strickly speaking, a true rocket not only carries its own fuel, but carries its own oxygen source. Thus, the V-1 or Buzzbomb is not a true rocket, because it depends on the atmosphere for its oxygen.

The common fireworks skyrocket represents one of the simplest types of rocket. As shown in the accompanying diagram, the spark follows the fuze into the cone-shaped cavity, and ignites the walls of the powder charge.

The charge usually consists of gunpowder; this makes it a true rocket, because gunpowder liberates its own oxygen. An explosion does not occur because the charge is so tightly packed the flame cannot penetrate it and can only burn on the walls of the cavity. As it burns, the cavity enlarges rapidly and the fuel is transformed into gas at high temperature and pressure. There is only one place it can escape, and consequently a jet goes roaring out of the nozzle, thrusting the rocket in the opposite direction. The attached stick guides the skyrocket straight upward because of its balanced weight, not by any "rail" action.

Rockets operate in obedience to Newton's Third Law of Motion: "For every action there is an equal and opposite reaction." It is the reaction to the escaping gases that push the rocket; it is not the push of these gases against the atmosphere. Rockets can operate in a vacuum faster, in fact, because the atmosphere only offers resistance.



Cross-Section of a Skyrocket

Basically, all modern rockets are driven by some form of rocket motor. Rocket motors can be divided into two classifications: Dry fuel (or solid propellant) and liquid fuel. The fireworks skyrocket is an example of the dry fuel type. All American rockets, with the exception of the "WAC" types, have dry fuel motors.

Basically all dry fuel rockets consist of a head or payload, and a motor. The combustion chamber of the motor contains the entire charge of propellant powder.

Smokeless powder such as is used in dry fuel rocket motors is a plastic material composed of nitrocellulose and nitroglycerin. A grain of smokeless powder is a mass of any shape and weight. Some single-grained rocket charges weigh more than a hundred pounds. The minimum cross-sectional thickness between two boundary surfaces is called the "web" of a powder grain. The web thickness controls the time of burning.

Rate of burning and pressure are interesting. The higher the pressure the faster the powder burns. Thus the rate of gas production by the propellant and the rate of gas ejection through the nozzle must be in balance at a pressure below the strength limit of the motor, to prevent rocket motors from blowing up near the launcher.

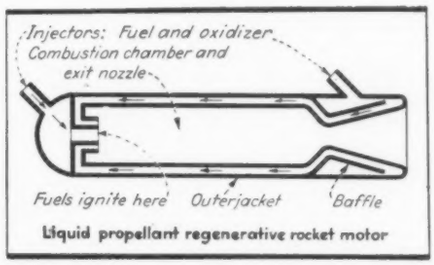
One or more large powder grains, and one or more nozzles at the rear end of the tube, can be used. The combustion chamber is usually called the "motor tube". A powder trap or "grid" is usually included to support and retain the charge during burning.

The largest dry-fuel military rocket developed by the Allies is the U. S. Navy "Tiny Tim" aircraft rocket. Its overall length is 10 ft. 3 in., its diameter slightly less than one foot, and its weight 1,284 lb. "Tiny Tim's" head is a semi-armor-piercing bomb that weighs 590 lb., of which 150 lb. is TNT. Its four grains of propellant powder weigh 146 lb. It amounts to putting wings on a pair of 12-inch guns and lengthening the guns' range to that of a medium bomber. Although its development was not completed until shortly before the war's end, it saw action against the Japs at Okinawa.

Liquid Propellant Rocket Motors

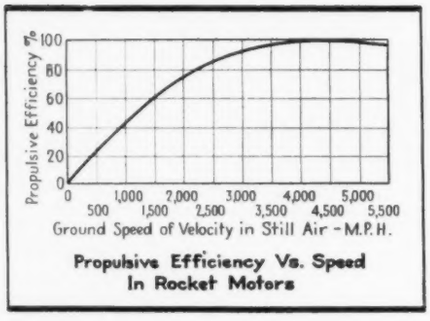
The great advance in rockets represented by the V-2 and the "WAC" rockets is the use of a liquid propellant motor.

The liquid propellant rocket motor develops forward thrust by the rearward expulsion of combustion products at supersonic velocity. The rocket motor as distinguished



Liquid propellant regenerative rocket motor

Either the fuel or oxidizer, depending on their characteristics, is introduced into the tail-end injector and used as a coolant. An igniter, not shown here, is usually included in the injector when the propellants used are not spontaneously combustible.



Propulsive Efficiency Vs. Speed In Rocket Motors

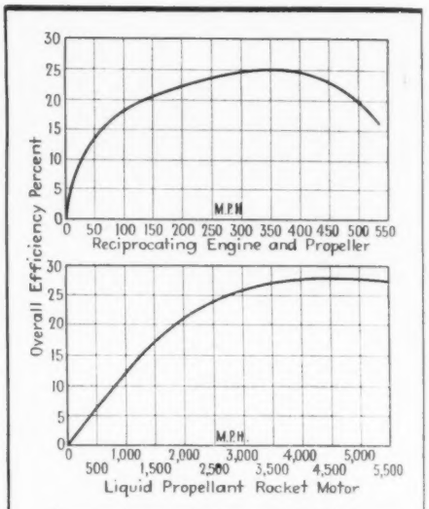
from current aircraft power plants of the jet propulsion or propeller type, does not operate at atmospheric oxygen, but depends upon a supply carried with the motor. The oxygen is furnished by an oxygen-yielding compound, known as the oxidizer, the fuel may be any hydrocarbon, both of these being known as the propellants. This engine under consideration utilizes liquids for propellants that are fed into the combustion chamber.

As shown in the diagram of the "regenerative" motor, fuel and oxidizer are burned in the combustion chamber, converting thermal energy into high-pressure gases that are ejected from the exit nozzle. Both fuel and oxidizer are liquids. These motors are surprisingly small for the amount of thrust delivered, because separate tanks are required for the propellants. A motor of 100 lb. thrust fits in the palm of the hand.

EFFICIENCY. Although fuel consumption is the yardstick of economy of the airstream and internal combustion engines, propellant consumption is the basic measure used for the rocket motor. The thermal efficiency does not change with the velocity of the rocket but does improve with increasing altitude because of reduced atmospheric back pressure.

The propulsive efficiency is a function of the thrust, the velocity of the rocket relative to the ground, the net thermal energy, and the kinetic energy of the propellants by virtue of their motion relative to the ground. Shown here is a graph of the propulsive efficiency versus the ground speed of a rocket for a jet velocity of 6,600 ft. per sec. (4,500 m.p.h.). As the ground speed approaches the velocity of the jet, a maximum efficiency of 100 percent is obtained.

A comparison of the overall efficiency versus speed for a conventional engine with propeller as compared with a liquid propellant rocket motor is illustrated in the accompanying pair of graphs. The efficiency scale is the same for both. The velocity scale of the rocket motor is ten times that of the reciprocating engine. Surprisingly enough, the rocket motor has a better overall efficiency than the best efficiency of the conventional type when it is operated in the proper speed range near its exhaust jet velocity. This is possible because 100 percent propulsive efficiency is obtained for the rocket where the airplane propeller utilizes about 80 percent of the available shaft power. Since the rocket motor has a 25 percent efficiency at 2750 m.p.h., it can get the same mileage per pound of propellant mixture as the conventional engine's mileage per pound of fuel at 350 miles per hour. The rocket can therefore travel the same distance in about 10 percent of the time. Even better efficiencies are in sight.



Comparison of Overall Efficiency of a Conventional Engine With Rocket Motor

An immediate application of liquid propellant rockets is assisting take-offs of heavily loaded aircraft the motors of which are not powerful enough to supply the necessary thrust. This is especially useful on water-borne planes and those that operate from airports at high altitudes.

Printed Electric Circuits

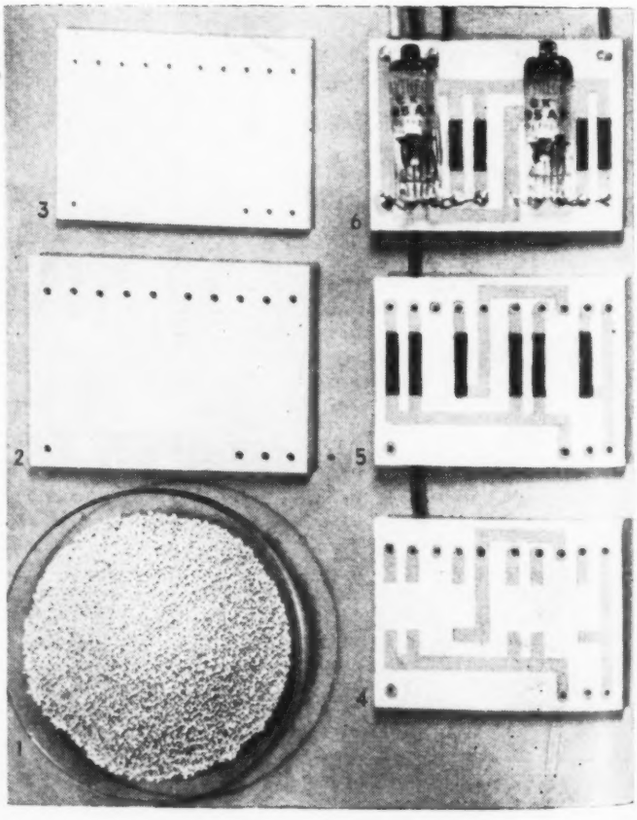
"PRINTING" OF WIRED ELECTRIC CIRCUITS complete with components on a plate of steatite ceramic, should make possible a reduction of size in radio, hearing aids, instruments and electronic control circuits never before thought possible. Developed by the Centralab Division of Globe-Union, Inc., this technique was perfected through the development of the radio proximity fuze. Wiring, resistors and capacitors become integral parts of a thin plate of steatite ceramic. Wiring is produced through the use of a silver paste printed or stenciled on the steatite ceramic and then fired at high temperatures to bond it firmly.

Resistor material composed of a carbon and resin mixture is sprayed or screened through accurately cut and positioned masks on the same plate, thereby making the larger, space-consuming type component unnecessary. Small, paper thin, ceramic disc capacitors are soldered directly to the proper silvered leads.

Other components, such as tubes of the new subminiature type which form a perfect complement to this type miniature circuit, can also be soldered directly to the leads provided on the plate.

The simplicity of this procedure make possible a unit that is inconceivably small, high efficient, practical and easy to service. As time-consuming hand wiring, assembly are eliminated by this process, lower production costs can be visualized.

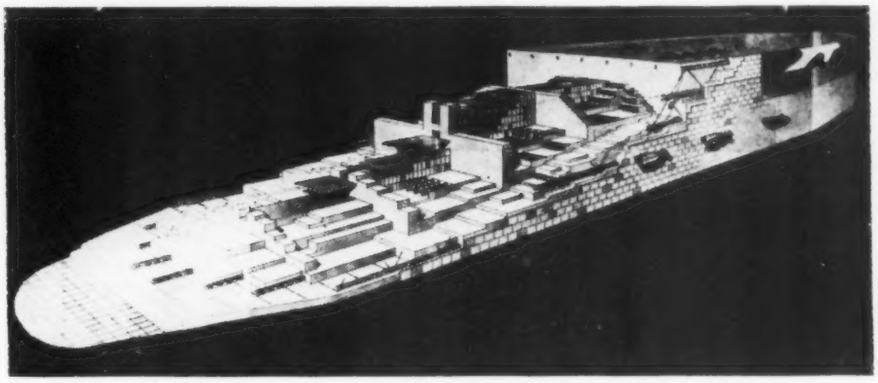
Shown in the photograph are the steps in fabrication of a "printed" electric circuit: (1) Mound of ceramic powder, (2) pressed and unfired plate; (3) fired plate showing the amount of shrinkage in firing, (4) silver leads masked, (5) resistors added, and (6) tubes, capacitors and leads soldered in place.



WASHINGTON NOTES

Science Legislation Fight Is Renewed in House

Ever since the publication of the famous report "Science—The Endless Frontier" by Dr. Vannevar Bush, distinguished head of the Office of Scientific Research and Development, the need for some kind of federal support of technical research has been apparent. Leaders of government, industry, education, the armed forces and the engineering profession have all proclaimed their support for a federally-sponsored research program. Last September, such a program took concrete shape in Congress with the introduction of approximately one dozen different bills covering federal support of research. In the months that followed, a controversy between two basically-opposed points of view on federal science legislation developed. This controversy was not limited to the halls of Congress—it spread rapidly to the world of business and science.



"Iceberg" That Never Froze—One of the first published sketches of "Project Habbakuk," this cutaway drawing shows construction details of the giant iceberg carrier once considered as an answer to a submarine menace in the Arctic regions. "Habbakuk" was to be made of reinforced ice blocks, 2,000 ft. long, 300 ft. wide and 200 ft. deep. The project originated in September 1942, got as far as a block model at Patricia Lake, Jasper, Canada, and was finally abandoned in December, 1943. The drawing is an official sketch from Combined Operations Headquarters.

Scientific Politicians—The most vehement struggle on this vital subject took place in the engineering and scientific professions, whose members in the pre-atomic era lived in ivory towers and were regarded as being above the mundane struggles of politicians and law-makers. Regular readers of this column are familiar with the details of the controversy; for the others, however, a brief recapitulation is in order.

The basic controversy on federal support of research revolved about how much control the government should exercise over the private research it sponsored. One side favored a minimum of control; the other camp wanted the government to have the final say on all issues. These two points of view were crystallized in the Senate in the form of two bills: The Magnuson bill, tending toward as little control as possible; the Kilgore bill, favoring maximum government control.

Paralleling congressional opinion, the Kilgore-Magnuson issue caused a schism in the scientific world. Under the leadership of Dr. Isaiah Bowman, president of Johns Hopkins University, a "Committee Supporting the Bush Report" (see January "Washington Notes" column) was formed, and came out four-square for the Magnuson bill. This committee, receiving the support of the four leading national engineering societies and the leading medical and biological societies, attacked the Kilgore bill, mainly on the single director (of the National Science Foundation set up under the bill) provision and on the patent provisions. The committee also objected, not so strenuously however, to the provision of the Kilgore bill setting up a "social sciences" division in the proposed National Science Foundation.

To counteract this scientific lobby, another group of scientists, whose moving spirits were Dr. Harold C. Uray of atomic bomb fame and Dr. Harlow Shapely of the Harvard Observatory, formed a "Committee for a National Science Foundation." This group, although calling for a compromise, leaned heavily toward the Kilgore idea of a Foundation: Control in the hands of a single, presidentially-appointed administrator; patents developed from federally-financed research to revert to the government, at the discretion of the administrator. The Magnuson bill, supported by the Bowman group, placed responsibility for direction of the Foundation with a board, made up predominantly of scientists; it outlined no definite patent policy, leaving each case to be judged by the board on its merits.

Compromise—After the mass of research bills on the Senate calendar had been narrowed down to two, a compromise Kilgore-Magnuson bill was freely predicted in Washington for several months. Finally, after heavy pressury from the Administration, a "compromise" was effected.

The new bill, S.1850, was sponsored both by Senator Kilgore and Senator Magnuson. It purported to settle the three basic issues in the Kilgore-Magnuson controversy as follows: (1) The Kilgore idea for a single administrator was retained, except that a 17-man "advisory" board, appointed by the president, was added; (2) Practically all the patent provisions of the Kilgore bill were retained, but were re-worded so that the harsh-sounding, "patents in the name of the government" was dropped; (3) The social science provisions of the Kilgore bill, previously objected to by the "Committee Supporting the Bush Report", were retained.

Both camps announced their support of the new bill, and superficially at least, all was sweetness and light in the councils of science. Except for an unimportant all-Republican bill sponsored by Senator Willis of Indiana, there seemed nothing to mar passage of the Administration-bred hybrid.

Came the Dawn—With the introduction into the House of a new research bill last month by Rep. Wilbur D. Mills of Arkansas, came the realization that the basic unbalance of ideas on government support of research had not been resolved. Bruce Brown of the Standard Oil Company and Bradley Dewey of synthetic rubber fame, both members of the Bush Committee, announced their rejection of the compromise bill, S.1850, and their complete support of the Mills bill, H.R.6448.

The Mills bill closely resembles the old Magnuson bill. As in the Magnuson bill, the new measure places responsibility for direction of the Foundation in the hands of a nine-man board, made up predominantly of scientists. Patents would be handled at the discretion of the board, which could assign them to private companies, "dedicate them to the public", or make them available at a fixed-fee royalty.

Shortly after Messrs. Brown and Bradley announced their support of the Mills bill, other members of the Bush Committee followed suit. Hearings on the new bill before the House Subcommittee on Interstate and Foreign Commerce opened with the following scientists expressing approval of the new bill: Dr. Vannevar Bush, president of the Carnegie Institution of Washington; Dr. Isaiah Bowman, president of Johns Hopkins; Dr. Homer Smith, New York University; Dean C. E. McQuigg, Ohio State University.

Secretary of War Robert P. Patterson and Assistant Secretary of the Navy W. John Kenney brought the endorsement of the War and Navy departments for the new bill to the hearings. Secretary Patterson further recommended procedures for the Division of National Defense of the Foundation to protect classified military information, and a minimum allocation of funds of 20 percent for national defense projects, instead of the 15 percent provided in the bill.

Thus, the research squabble is out in the open again. Neither the Kilgore bill, representing the government-control scientists, nor the Mills bill, representing the freedom-for-research men, have been passed in their respective houses of Congress. With labor

legislation as the big issue in this session, it is certain that the research deadlock will not be settled before Congress recesses.

Exit Groves

The skids have been greased for easing Maj. Gen. Leslie R. Groves out of the atom business. Actually, on paper, he is no longer atom boss. President Truman has named the general one of two assistants to the Chief of Engineers—and Groves remains head of Manhattan District technically on loan from the chief's office. Furthermore, Army has created a G-6 division of its General Staff, on a level with personnel, training, intelligence, operations and supply, to have full policy authority over research and development. A general officer (not Groves) with scientific background will soon be picked for the new post and then Manhattan District will be solely an operating agency within G-6's policy determinations.

There is a continuing pressure campaign, both from within and without, on both Secretary of War Patterson and General Eisenhower to complete the Groves ouster by naming the new head of Manhattan District. To the Army brass behind this campaign, the matter comes under the heading of improving Army public relations. Apparently the only delay is to make certain there will be no domestic atom-control legislation at this session; passage of a bill would automatically end Groves' job.

Atomic Sidelight—The Army isn't overlooking that if it continues in charge of atomic development until next year it will be that much easier to leave the job there permanently—thereby enabling it to win by attrition the military vs. civilian battle for control.

Metal Lens Focuses Microwaves

A METAL LENS capable of focussing radio waves as an optical lens focusses light has been developed at Bell Telephone Laboratories. The new lens is expected to find its most widespread application in microwave radio relay systems such as the New York to Boston channel now under construction. While these new systems are designed primarily as adjuncts to the telephone network, they are expected to find additional use in transmitting pictures, radio broadcasts and television programs.

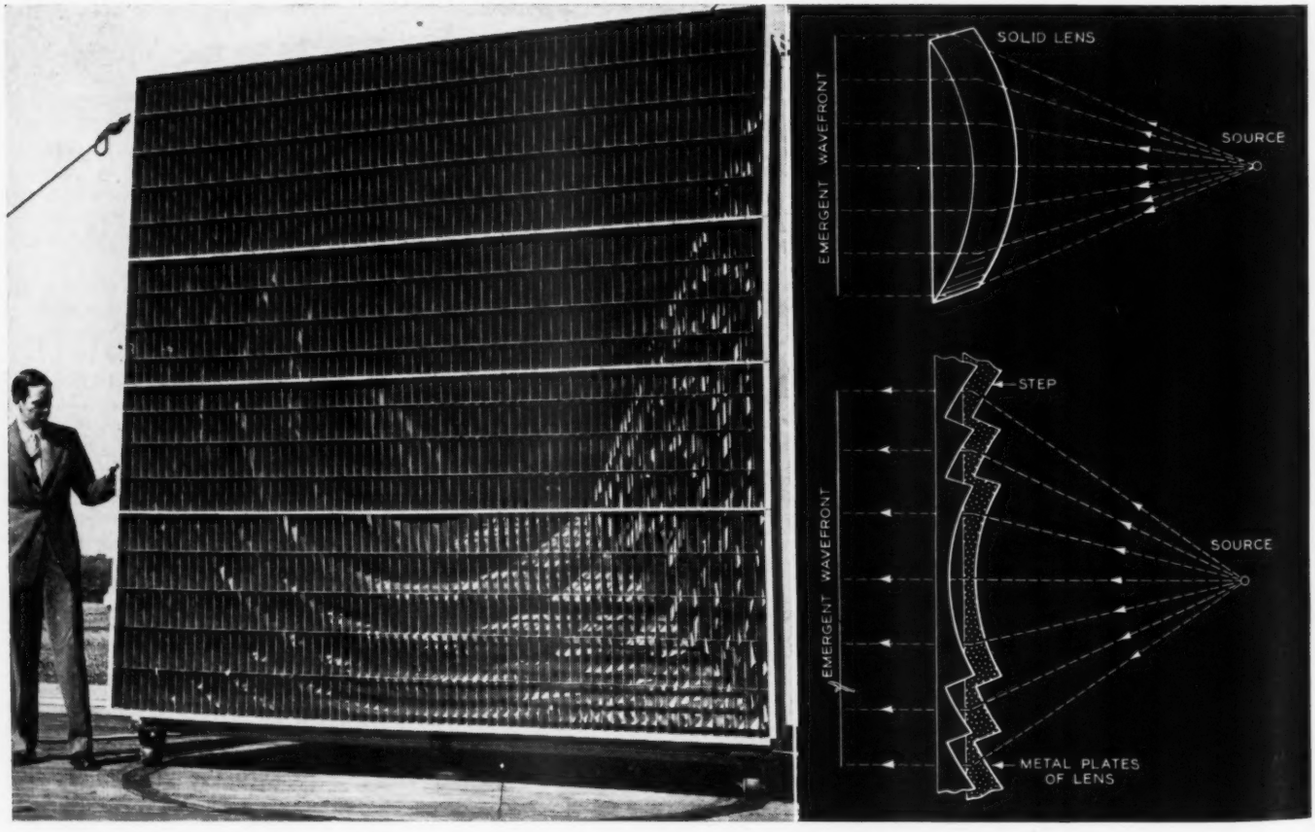
The very short waves used in microwave communications, unlike longer commercial broadcasting waves, do not follow the curvature of the earth but shoot off into space. Communication over long distances requires the use of relay stations. To obtain this short-range transmission between successive relay stations with peak efficiency and least interference, the wave energy must be focussed into a narrow beam.

The metal lens, which can focus radio waves into the sharpest beam of its kind ever produced, has solved this problem.

An array of metal plates was designed to focus radio waves just as effectively as a solid lens might focus them if regard were given to the fact that the edges of the wavefront would be advanced rather than retarded in transit. This structure was easier to build, move and maintain than an equivalent solid lens.

The metallic lens speeds up the edges of the beam relative to the center so that the wavefront is flattened. The metal plates are longer at the sides than at the center, bringing the laggard edges up in line with the center.

Bell Telephone Laboratories



(Left) The metal lens antenna, shown with its inventor, Dr. Winston E. Koch of Bell Telephone Laboratories. (Right) Contours of solid or dielectric lens and metal plate lens, both designed to convert microwaves from a point source radiator into a parallel-sided beam. Because of their opposite effects on wavefronts velocity, they must be built of converse shape to produce the same focussing effect. In "stepped" lens, each concentric zone acts as an individual lens.

RESEARCH NOTES

Forum Keynote Is Science's Role In Advancing Civilization

Science, which treated a powerful array of wartime forces and agencies, faces its severest test in its ability to turn its creations to the benefit of all civilization, leaders in science, engineering and education were told recently at the George Westinghouse Centennial Forum.

The Forum, which brought together for the first time since V-J Day many of the men responsible for major wartime scientific advances, is being sponsored by the Westinghouse Educational Foundation in commemoration of the 100th anniversary of the birth of George Westinghouse, noted inventor and industrial pioneer.

Forum Sidelights

If scientists ever succeed in developing a practical method for utilizing all the energy stored up in uranium, future generations won't have to worry much about dwindling supplies of our natural resource, coal. This was indicated to participants in the George Westinghouse Centennial Forum in Pittsburgh, Pa., by Dr. Enrico Fermi, Professor of Physics at the University of Chicago, and a Nobel Prize winner for his work on atom splitting. The fission energy of uranium is roughly 3,000,000 times that of an equal amount of coal.

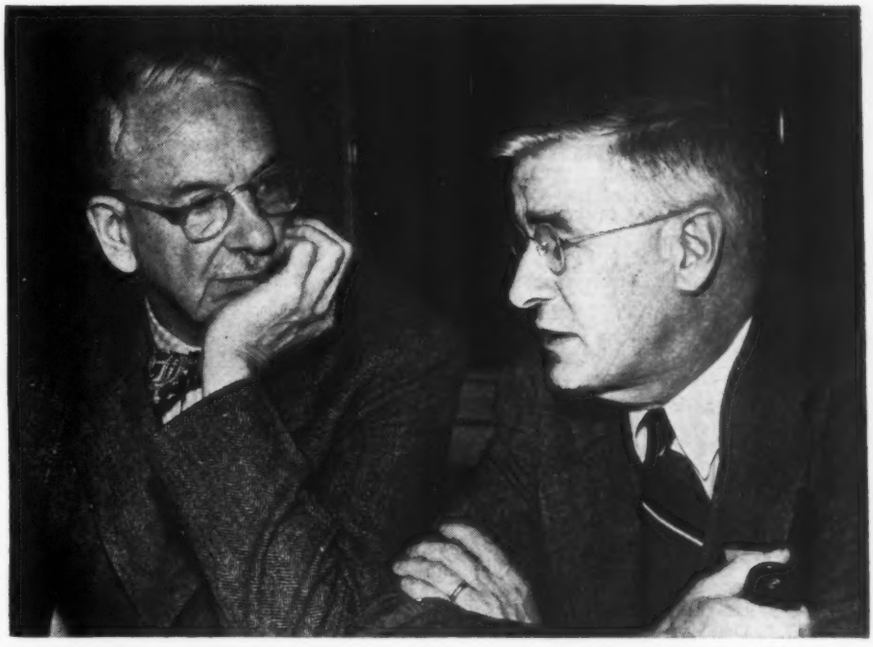
The energy value of one pound of uranium is so great that even an enormous increase of cost of this material may not interfere with its economical use as a source of power. Indeed three million tons of coal, equivalent in energy content to one ton of uranium, cost about eight million dollars. Consequently, as far as the cost of the raw materials, uranium and coal would become equivalent for a price for uranium of $4,000 per pound. Before the war the cost of uranium was about $2 a pound so that an increase of the order of a thousand times the pre-war price would not be necessarily uneconomical.

Dr. Vannevar Bush, Director of the Office of Scientific Research and Development, urged the removal of burdensome restrictions on small business, declaring that the dead hand of bureaucracy lies today too heavily on the controls of smaller organizations in this country.

In this portion of our system, Dr. Bush declared, where about 30 percent of manufacturing wage earners are employed, but where over 90 percent of our manufacturing establishments are found, we sadly need a return to freedom of enterprise, to a situation in which the employer and his few score of employees tackle their own problems and settle their own differences without the forced intervention of some unwanted and unneeded functionary.

If more persons were technically or mechanically minded, science and industry could furnish even more marvelous mechanisms for their use and comfort, according to Dr. Frank B. Jewett, President of the National Academy of Sciences, at the George Westinghouse Centennial Forum.

It is not inconceivable that a system could be developed that would permit any one of many million telephone subscribers to dial any other one directly without the aid of an operator and with fully automatic registration of all data needed for billing. The system would be so intricate, however, that it is most unlikely that the necessary information for operation could be placed in the hands of each user or that they would be able or willing to operate such a system.



A. W. Robertson, Chairman of Westinghouse Electric Corporation, talking with Dr. Vannevar Bush, Director of the Office of Scientific Research and Development, at the Westinghouse Centennial Forum.

Army Air Forces Plan Air Research Center

Army Air Forces have disclosed plans for the construction of an Air Engineering Development Center for the purpose of applying the results of research to the development of air weapons required by the AAF for national defense.

For the future, General Curtis E. LeMay, Deputy Chief of Air Staff asserts that two prerequisites are clear: (1) Fundamental research in aeronautics must never again be interrupted, and (2) There must be adequate development facilities independent of research facilities, where the specific problems connected with the design and construction of aircraft and missiles can be solved.

While the Development Center is primarily intended to serve the military and military development contractors, it should release for beneficial peacetime purposes all developments achieved which would promote the commercial interests and welfare of the people of this nation, General LeMay recommended.

Immediate planning, said the general, for the future development of any such facilities must be projected far beyond the possibilities known today for the pilotless aircraft, winged missiles, jet propulsion, radar and atomic bombs left from World War II. It must embrace all fields, including the following:

1. Supersonic aircraft, piloted and pilotless; winged missiles having velocities approaching the meteoric.
2. Nuclear energy applications for propulsion of aircraft and missiles, as well as for other atomic devices which may evolve in the future.
3. Flight and survival equipment for use above the atmosphere, including space vehicles, space bases and devices for use therein.
4. Detection control and destructive apparatus, including the utilization of the energies represented by all spectra. (Light, heat, magnetic and all other forms of energy and forces which may exist in the various densities of the several masses or space areas in which men could be concerned, must be exploited thoroughly and continuously.)
5. Aircraft and missile operating technique development, and the organizational structure thereof.

General LeMay said that Wright Field, where the AAF has established headquarters for much research and development, could not accommodate the additional installations proposed for the Center, particularly with regard to available power, acreage, and climate. Neither can aircraft manufacturers and universities be expected to erect such costly equipment.

Envisioning a main location encompassing

100 square miles and additional auxiliary fields and ranges, the AAF points out that large blocks of economical electric power in the range of one million horsepower must be continuously available to supply the connected lead of the proposed Center. Large quantities of the coldest water must be available for an estimated capacity of 250,000 gallons per minute. The site location must have proper terrain providing relatively level ground for the construction and hilly terrain for shielding hazardous developments. In addition, the location must provide normal facilities for a self-sufficient community.

The proposed facilities for the Development Center have been broken down into eight sections as follows:

FLUID DYNAMICS. The Fluid Dynamics Facility is proposed to include five wind tunnels and a Components Laboratory for individually testing the component parts of propulsion systems. The proposed Wind Tunnels form a well balaced group covering the entire testing range, from 0 to 7500 miles per hour.

THERMODYNAMICS. The Thermodynamics Facility will include special equipment for the study of heat transfer and insulation, the effects of velocity pressure distribution and boundary layers, combustion chamber phenomena and nuclear fission phenomena.

STRUCTURE AND MATERIALS. This facility will provide equipment for testing the complete structure and component parts of aircraft and missiles and will require a materiels processing area with furnaces, forges, presses, rolling mills and welding equipment. In addition, the Physical, Chemical and Structures Test Areas will house laboratories with all equipment necessary to analyze materials being developed.

ELECTRONICS AND WAVE PHENOMENA. This facility will include equipment for testing and developing radio control, telemetering, navigation, radar, loran, television and homing devices.

PHYSIOLOGY. This facility will be designed to include special test chambers for determining the effect of acceleration, atmospheric conditions, vibrations, noise, and odors on the human body, under simulated flight conditions.

FUELS AND PROPELLANTS. Special equipment will be required in this facility, in addition to the standard chemical and physical equipment to determine the octane or cetene number, pour point, flash point and other specification requirements for fuels. Installations of machinery will be necessary for the production of liquid oxygen and other substances which could not be stored in large quantities for an appreciable length of time.

INSTRUMENTS. This facility is proposed to have five test areas for special analysis of optics, mechanics and electronics.

FLIGHT ENGINEERING. This facility is proposed to include runways, shops, hangars and general installation equipment required for full scale testing of personnel carrying units. In addition, equipment for launching missiles and other non-personnel carrying units will, be required.

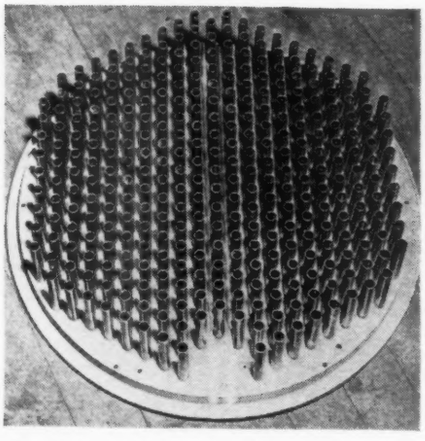
Sonar Location of Submarines

SONAR, the only effective method of detecting completely submerged submarines, was a major factor in the defeat of the U-boat and the winning of the Battle of the Atlantic. A majority of the 996 enemy submarines sunk during the war were detected and located by sonar.

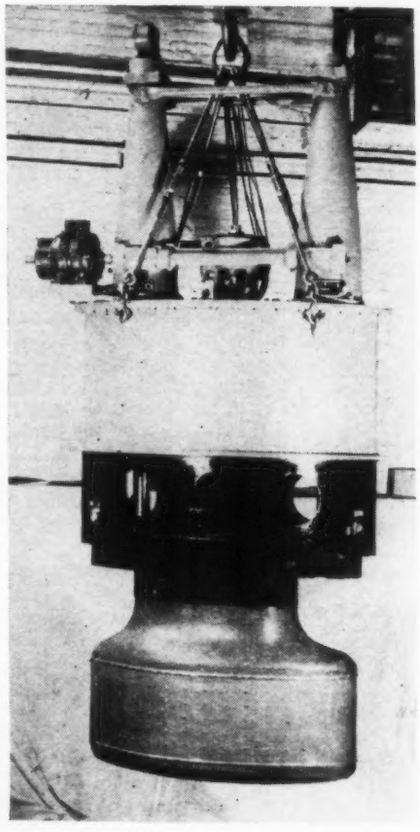
The underlying principle of ranging sonar is the principle of the echo. Sound waves are sent through the water, and are echoed back to the sender when they strike an underwater object. Between that simple principle and the development of equipment capable of detecting and tracking moving submerged submarines, however, lie years of scientific research and experimentation that spanned two wars.

The first experimental echo ranging sets operated at frequencies between 20,000 and 40,000 cycles per second. These supersonic voltages were generated by a transmitter that fed the transducer, the combined radiating and receiving unit, which protruded through the ship's bottom. The four-inch thick transducer consisted of quartz slabs sandwiched between steel disks about 16 inches in diameter. It "pinged" out one-quarter second pulses of energy which traveled horizontally in a cone-shaped path. When part of the sound wave struck the target submarine, a small portion of the energy was reflected back to the transducer, which in turn fed the "echo" through an electronic amplifier to earphones and a range, or distance, indicator. The direction in which the transducer was facing indicated the target's bearing.

When the United States entered the war, the Navy's 170 destroyers were the only United States surface craft fitted with echo ranging sonar. During this period U-boats were sinking ships faster than we replaced them, and we were losing the Battle of the Atlantic. Our success in attacking submarines after we detected them was less than five percent—95 out of 100 got away. Sonar was detecting the U-boats, but in the crucial moments of the attacks, something was inadequate.



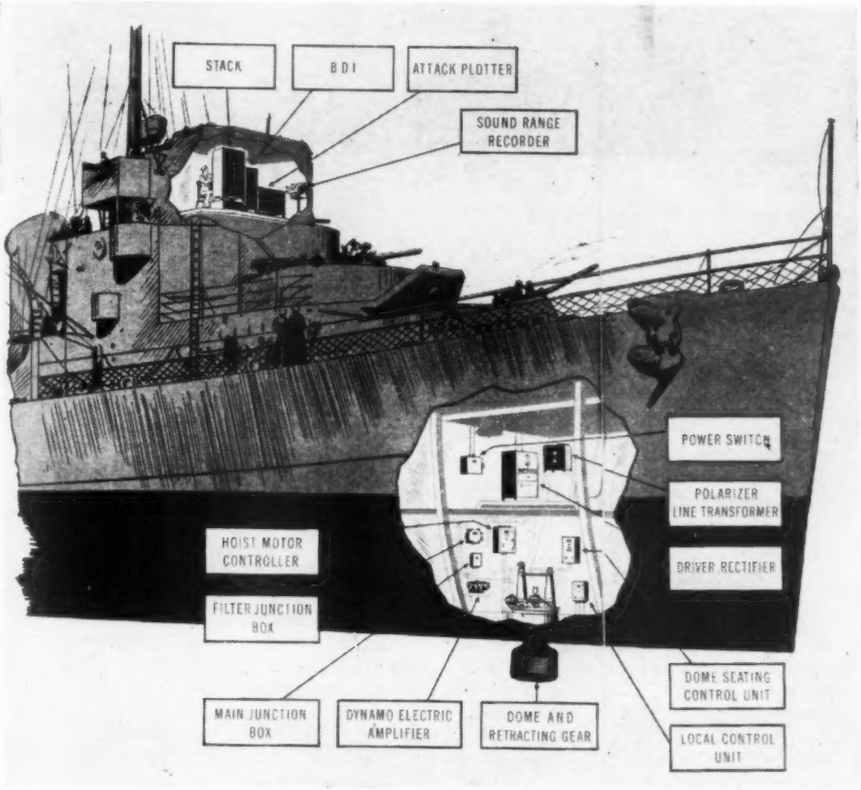
Rear view of the diaphragm of a sonar transducer. Electric current is sent through coils wound around the nickel magneto striction tubes. This causes the tubes to change length rhythmically and set up a vibration in the diaphragm. The face of the diaphragm which is in contact with the water transmits the vibrations as sound waves.



Seaboard unit, showing retractable streamlined dome. The dome and retracting gear can be operated from the lower sound room in which it is located, or from the stack.

To find the solution, the Navy Department assigned to the National Defense Research Committee the project of providing statistical analysis of past operations, theoretical detailed studies of tactical doctrines, and operational analysis of sonar attacks and of equipment and weapons in order to prescribe for their best use and to assist in improving their design.

The scientific research groups submitted



U. S. Navy Photographs

Cross-section of a combat ship shows sonar equipment installations, both in the pilot house or control room, above, and below, in the lower sound room, in which the retractable gear and dome is located.

certain confirmations of the prewar work of our Naval officers and scientists. They found that sound travelling in warm surface water bends sharply downward when it passes through a thermocline, a region where temperature decreases sharply with depth, and results in very weak echoes being returned from submarines beneath the thermocline; that thermoclines may cause loss of sonar contact; that U-boats may hide under thermoclines, and that a shipborne, cable-lowered baththermograph for recording temperatures and pressures to locate thermoclines could be used to locate these ocean effects. Their confirmations, together with the baththermograph, prediction tables and tactical rules were supplied to ships for use in predicting maximum echo ranges, spacing between escort vessels and the interval between successive sonar pings.

The engineering groups enlisted the aid of additional manufacturers and furnished a gyro-controlled device to keep the sonar beam directed on the U-boat during an escort's maneuvers or turns, an electronic scope to indicate visually whether the sonar beam tended to lose contact due to the operator moving the beam either to the right or left of the U-boat, and a control device which reduced the heavy reverberations resulting from sudden sonar pings which cause the surrounding water to act like an empty hall with bad acoustics. The control device also reduced undesirable interfering echoes from seaweed, shallow water bottoms, tidal currents and ship wakes.

Accumulated instruments which appended the sonar had been incorporated into the "console sonar" which contained new features. They included devices for detection of mine fields, calculation of U-boat depths with the echo-sounder, indication of oncoming torpedoes traveling as high as 40 miles per hour, and accessories which indicated to accurate ranges, bearings and time to fire weapons. Unescorted fast ships were being fitted with hydrophone torpedo detectors.

The Navy's submarine echo-ranging sonar had been augmented by (1) A topside listening hydrophone consisting of a three-foot long two-inch diameter magneto-striction tube having excellent directional accuracy on sounds up to about 10 miles distance in average water conditions and (2) a shipboard listening trainer attached to the sonar to provide practice in estimating speeds of various ships by their propeller rhythm.

Foreign Standards And Patent Activities

THE GOVERNMENT OF INDIA is now considering establishment of a Central Standards Organization, to bring more order into the slipshod techniques which are hampering India's industrial growth and foreign trade. The Indian Institution of Engineers has been campaigning for the move, and has drawn up a detailed plan for such an organization.

Though standards work has not progressed very far in India, the so-called "Agmark" standards have been fixed for certain foodstuffs and the Railway Board has laid down standards for certain articles. Large industrial concerns have also developed some standards.

* * *

FRENCH PATENTS DUE TO EXPIRE after August 21, 1939 and before publication of the official decree which will fix the legal date of cessation of hostilities have been granted a new lease of life under a special French law. Principal benefits of the law, which is similar to one passed at the end of the last war, are as follows:

1. Patents in force August 21, 1939 and due to expire before the end-of-hostilities decree may be extended for six months from the date of that decree, upon demand of the patent-holder and payment of a tax.

2. Patents which could not be exploited normally during the past years, because of the war, may be extended for a period of five years in all, one year at a time. Requests for these extensions must be presented, with justificatory material, no later than six months after the official end of hostilities, and at least three months before the patent was due to expire. Exceptions to this last rule may be given, however, if delay in applying for extension is due to the war.

3. Foreign-owned patents are covered under the same provisions, if their owners are nationals of a country subscribing to the International Convention of March 2, 1883, and if the country in question grants to French citizens the same patent-prolongation benefits it may have offered its own nationals.

Licensing arrangements will continue as before, for patents whose life is prolonged under this law. Licensees are given the option of withdrawing from their contracts, however, up to three months after the patent would have expired if it had not been prolonged. The prolongation law is dated July 20, 1944.

* * *

The Chinese Government is seeking actively to promote the advancement of simplified practice and standardization in Chinese industry, according to the Department of Commerce.

The work of the Chinese agency has recently been reactivated under the Ministry of Economic Affairs, according to the secretary of the Chinese Standards Committee, who recently visited the Bureau. This official made specific and detailed arrangements with the Simplified Practice Division for the complete interchange of experience in the field of simplification.

The Chinese Standards Committee will furnish English translations of all their standards, while the Bureau will keep the Committee continuously informed regarding

manufactured articles and commodities that are simplified by American industries—things that China will purchase in the United States for use by the Government as well as private concerns and individuals.

* * *

A CHINESE PATENT OFFICE, according to Chinese government officials, probably will be set up as a branch of the Ministry of Economic Affairs sometimes in 1946. The new department probably will be patterned after the U. S. Patent Office, which was visited and studied last year by Tan Po-yu, Vice Minister of Economic Affairs. The Executive Yuan recently promulgated a series of patent laws under which the new office will operate.

* * *

DUTCH ATTORNEYS have organized a movement to have the Netherlands Patent Office in the Hague serve as the patent registration center for Europe now that Berlin is no longer suitable. The Netherlands office is said to have a well-trained staff and to possess an adequate library of literature from all countries.

* * *

The Indian government is expected to create a bureau of standards as a result of a report strongly favoring the proposal by a committee of the Indian Institution of Engineers.

* * *

Norwegian industry expects to benefit from the more than 5,000 German patents registered in Norway over the past twenty years. These patents, many of which have never been exploited, are now in the hands of the Norwegian Directorate for Enemy Property and will be leased to domestic firms on a license basis at a reasonable charge.

Lockheed Aircraft Corporation

"Speedpak" Increases Aircraft Payload

LOCKED IN POSITION with more than four tons of cargo inside, a Speedpak external cargo carrier fits against the underside of a Constellation fuselage. Designed by Lockheed engineers, the Speedpak enables more cargo to be carried outside of the airplane than can be crammed inside the fuselage of a standard twin-engine airliner. This is accomplished without disturbing the interior arrangement of the Constellation or cutting down its normal passenger load. The Speedpak can be wheeled to the plane and raised into place in two minutes by a built-in electric hoist. A drop of only 10 miles an hour in top cruising speed results through use of the Speedpak, but the Constellation's flight characteristics are not adversely affected. Baggage capacity of the Speedpak is 400 cubic feet, almost doubling the Constellation's original capacity of 450 cubic feet.

SAE Summer Meeting Features New Designs, Research Emphasis

ENGINEERS ADDRESSING the Summer Meeting of the Society of Automotive Engineers in French Lick Springs Hotel offered glimpses of possible 1950 automobiles. Describing before the Passenger Car Session what could happen, they talked of future cars equipped with supercharged engines, of engines with extremely high compression ratios, and of cars with independent wheel suspensions, hydraulic steering, rubber torsion springs.

Earl Bartholomew, of Ethyl Corp., Detroit, Mich., said that present and prospective motor fuels offer real possibilities for high fuel economy and great power output. Gains potentially are similar, he explained, whether superchargers or higher compression ratios are employed.

Motor fuel octane numbers and antiknock ratings on the order of 86 premium and 80 regular grade fuels prophesied for 1950 already are available, Mr. Bartholomew reported. He said that short, compact vee or opposed engines of 8.5 compression ratio operating on fuels in the 100-octane range appear to be inviting, especially by way of fuel economy, which further could be enhanced by progress in designing automatic transmissions.

RUBBER SPRINGS, HYDRAULIC STEERING. Tomorrow's small, light five-passenger car, equipped with rubber torsion springs, independent wheel suspension, and hydraulic steering was exhibited and described by A. S. Krotz, R. C. Austin, and L. C. Lindblom, of B. F. Goodrich Co. Akron, Ohio. Steering was said to be accomplished by two balanced hydraulic circuits, one comprising a hydraulic tie rod between the front wheels, the other a pump circuit, with both kept under minimum positive pressure by a spring-loaded reservoir. Rear suspension was described as of the independent swinging axle type, with a universal joint at each wheel. A hydraulic constant level mechanism, applied to all four wheels, was reported to maintain the designed chassis height regardless of load or of movements of wheels and springs.

CAMERA PRODUCES NEW DATA ON LUBRICATION. Behavior of the oil film on the piston of an internal combustion engine, representing new technical knowledge for engineers directly helpful in designing and constructing motor vehicle powerplants, was described at the Fuels & Lubricants Session.

Methods and results from two photographic studies of what happens inside the cylinder of an internal combustion engine were reported as providing engineers at long last with exact knowledge of the perform-

MEETINGS

JULY 18-19
Institute of Aeronautical Sciences—Summer meeting, Hotel Hollywood-Roosevelt, Los Angeles, California.

AUGUST 19-23
National Association of Power Engineers—Annual convention and Power Show, Hotel Cleveland, Cleveland, Ohio.

AUGUST 20-23
American Mathematical Society—Summer meeting and Colloquium, Cornell University, Ithaca, N. Y.

AUGUST 22-24
Society of Automotive Engineers—West Coast Transportation meeting, New Washington Hotel, Seattle, Wash.

ance of piston, rings, and oil film during the full cycle of induction, compression, explosion, and exhausting.

Visual studies, using glass cylinders, camera, and both scattered and fluorescent lighting, were described by M. C. Shaw and T. J. Nussdorfer, of the National Advisory Committee for Aeronautics, Cleveland, Ohio, as revealing that piston skirt lubrication is a function of the relative angular positions of the piston rings and the lateral motion of the piston. They said that piston rings were observed to rotate as rapidly as one revolution per minute at engine speeds of 1,000 rpm. They estimated the oil film on the faces of piston rings to be only one-ten-thousandth of an inch thick, perhaps less.

Similar visual studies, but made without combustion in a glass-cylinder engine by S. J. Beaubien and A. G. Cattaneo, of Shell Development Co., Emeryville, Calif., were presented as directly helpful to designers of pistons, piston rings, and cylinders, as well as to refiners of lubricating oils, in finding the best solutions for such problems as ring sticking, scuffing, and control of oil consumption and wear.

Analysis of transient vibration associated with combustion roughness of in-line engines was reported by Arthur S. Fry, John Stone, and Lloyd Withrow, of Research Laboratories Div., General Motor Corp., Detroit, Mich., to indicate that more is to be gained in solving this problem by altering the mechanics of the vibrating system than by controlling combustion chamber shapes.

PUBLIC ADMIRES RADICAL, BUYS CONSERVATIVE. Public enthusiasm for new and radical designs should not be mistaken for desire for possession, R. E. Bingman, industrial designer, Detroit, told the Body Session.

Motor vehicles or aircraft without a hood in front of the operator are not acceptable even to the experienced, Mr. Bingman reported, because people have become conditioned to the negligible protection and false security of the hood. Even an obviously unnecessary projection, just an illusion of hood, gives them a feeling of security, he added, and allays fear and buying resistance.

Industrial design has become a science of logical compromise between what the public has been conditioned to using, that which engineers and manufacturers desire to produce, and that which the public will accept, said Mr. Bingman. He added that it is the job of the industrial designer to ascertain the purpose of a product, how it will be used, and by whom; then to apply imagination, ingenuity, and artistry to a product which will achieve human acceptance.

Paid Academic Leave For Monstanto Scientists

Inaugaration of an academic leave for industrial scientists at Monsanto Chemical Company to enable them to return to universities of their choice for an academic year of study at full salary, has been announced by Dr. Carroll A. Hochwalt, Monsanto's Director of Central Research.

Addressing the National Industrial Conference Board, Dr. Hochwalt said the leave of absence was established to encourage the scientific work and development of technical personnel in physics, chemistry and chemical engineering. Four leaves will be granted each year, and will be made on the basis of especially meritorious service and outstanding performance in scientific work carried out at any period and in any location in the service of Monsanto.

The recipients will return to campuses of their own choosing for refresher courses and original research. They will receive their regular salaries during this time. Such a plan, it is felt, will not only be beneficial to the individuals but also will help to introduce fresh points of view in industrial research.

Dr. Hochwalt stated that it was incongruous to believe that scientific and technological advances were results of wartime rather than peacetime effort. "It is only in times of peace that we add to our scientific resources," he said. "Then it is that we train our personnel, uncover basic principles of science and speculate on ways in which these may be used." There is no opportunity to do this in time of war, he added. All that can be done then, he said, is to ask already trained personnel to apply previously established basic facts to the needs of the moment. "During the war years," he continued, "we lived almost entirely on our principal; we depleted our scientific resources without adding to them."

Dr. Hochwalt said that as a result of closely integrated efforts during the war, industrial scientists and academicians have learned to work together and have developed better understanding and mutual respect. Continuation of this teamwork must be encouraged, he added, for the greater development of both.

Stating that industrial research has had a phenomenal growth in the United States, Dr. Hochwalt said that in 1920 approximately 300 industrial laboratories were in existence with a research personnel of about 7,500 and a total budget of $30,000,000. In 1940, he stated, the number of industrial laboratories had increased to 2,350 with 70,000 scientists and expenditures of over $250,000,000. He predicted that by 1950, industrial research will have increased two hundred fold since 1920 with about 3,500 laboratories and 150,000 personnel.

DISCUSSIONS AND COMMENTS FROM READERS

"The Suppression of Patents"

To the Editor:

Mr. Morrow's definition of patent suppression as "the non-employment of inventions because of various social and economic factors" robs the article of any particular significance. Of course for perfectly good reasons the inventions of many patents are not used. Suppression should refer only to wilful non-use against the public interest.

We agree with the statement of the author that "The grant by society of exclusive rights for a limited period is considered a just reward to the inventor for a permanent enrichment of the useful arts".

Despite the misleading assertion of the Anti-Trust Division of the Department of Justice, our Supreme Court from beginning down to date has taken the position that patents are property and as such are entitled to constitutional protection given to private property in general.

The monograph contains some misstatement of fact bearing on the question under consideration. For example, referring to the vacuum tube developments of a telephone company he states that "no radio tube manufacturer had, as a matter of fact, been licensed to make those tubes". As a matter of fact every manufacturer of tubes for radio purposes was licensed to manufacture those tubes. This is brought out by later testimony before the temporary National Economic Committee.

As to the statement that "corporations buy all possible ways for performing a particular operation. Most of these devices or processes are not used; they are acquired to prevent competitors from entering the field". If such is a fact, the anti-trust laws provide an adequate remedy to prevent such acquisition of competing patents.

—GEORGE E. FOLK
National Association of Manufacturers

"Poor Recognition Breeds Frustration"

To the Editor:

In your April editorial, "Poor Recognition Breeds Frustration," you state that there is now a deficit of 17,000 trained engineers and by direct implication that these are design engineers. The Bush report clearly points out that by 1955 there will be an estimated deficit of 17,000 men holding doctorial degrees in all fields of science and technology. I am looking forward to your amending these statements.

—J. P. WAGGENER.

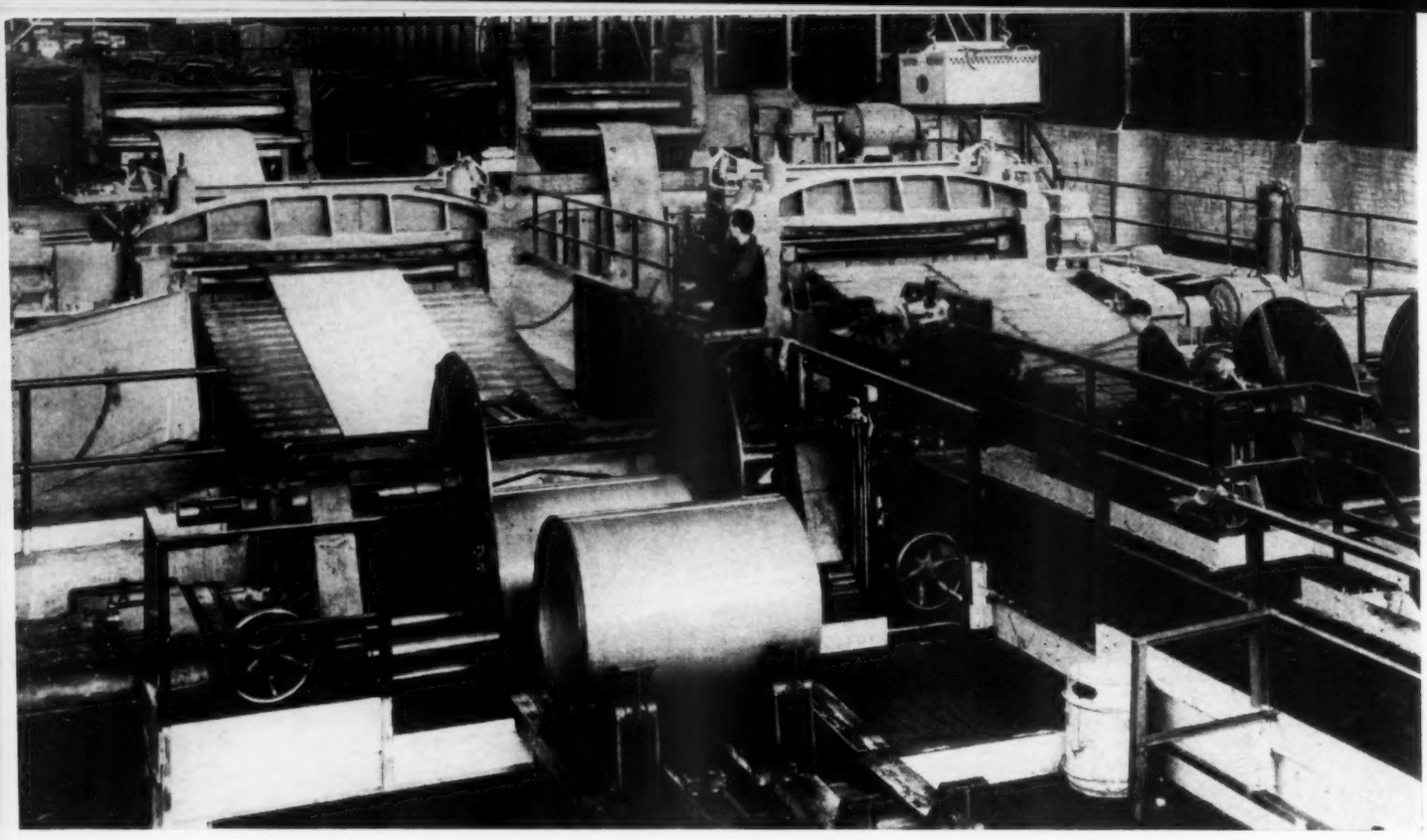
To the Editor:

May I compliment you on the excellent editorial "Poor Recognition Breeds Frustration" which appeared in PRODUCT ENGINEERING for April, 1946.

Your magazine is not generally read by management. If you could arrange to have it appear in some of the magazines which are read by those high in management, I am sure it would serve a very useful purpose.

—J. F.

EDITOR'S NOTE: Other publications please note: Reprint permission is hereby granted.



Adjustable-voltage control is useful for industrial processes such as these continuous pickling lines in a steel mill.

Adjustable-Voltage Control Basic Principles and Circuits

E. U. LASSEN
Assistant Chief Engineer, Cutler-Hammer, Inc.

Operating principles, major advantages, application factors, and performance characteristics of the adjustable-voltage control system are given. The use of dynamic and regenerative braking, manual and automatic control, and five control schemes using adjustable-voltage control are explained and discussed.

DESIGNERS of industrial machines or processes that require exacting operating characteristics such as smooth acceleration, wide speed range, or group operation often find that adjustable-voltage control gives the best overall performance. Since there are several forms of adjustable-voltage control, this article will explain the fundamental circuit and discuss some of the typical modifications of the basic circuit that provide specialized control.

Basic System

The basic adjustable-voltage control system consists of a d.c. generator that supplies an adjustable voltage to the armature of a shunt wound d.c. motor with a constant field excitation. The fundamental circuit is shown in Fig. 1, consisting of an a.c. motor driving a d.c. generator and exciter, a d.c. motor for driving the load, and a rheostate for controlling the current in the generator field. The armature of the generator is permanently connected to the armature of the motor forming an electrical loop circuit. By gradually increasing the current in the generator field, the generator supplies a smoothly increasing voltage to the armature of the motor and the motor may be started without using accelerating resistors or contactors in the armature circuit. The shunt field of the generator and the shunt field of the motor are supplied with constant d.c. voltage, usually by the exciter as shown. A squirrel cage induction motor usually drives the generator and the exciter, but it may be a diesel engine or any other suitable prime mover.

Since in this system the field excitation of the d.c. motor remains constant, the speed of the motor is proportional to its countervoltage, and hence, the speed is also substantially proportional to the voltage supplied to the armature of the motor. Thus, by adjusting the applied voltage, the speed and direction of rotation of the motor are easily controlled. Referring to Fig. 1, when the resistance of the rheostat in the generator field circuit is a maximum, the generator field current and field strength are

low, so that the generator output voltage is a minimum. This is the condition for starting the motor, since the motor draws a low starting current that can be controlled to provide any desired starting torque. Once started, as the resistance of the control rheostat is decreased the generator voltage increases and the motor speed increases.

For large machine requiring motors of several hundred or several thousand horsepowers, the generator field rheostat might become so large that a separate adjustable-voltage exciter would be preferred for supplying the generator field. The control rheostat then controls the field circuit of the exciter. This adjustable-voltage exciter is used in addition to the constant-voltage exciter, which is still needed for supplying the motor field and the controller circuits.

Six Advantages

Advantages of the adjustable-voltage control system include:

1. Control of large amounts of power by relatively small and inexpensive devices that control field circuits. As an example, the speed of a motor rated 250 hp. 230 volts can be controlled either by means of adjusting the 11 ampere generator field current or by employing resistor steps and contactors in the 900 ampere armature circuit.

2. Speed control over wide ranges with great economy in power consumption. Low power losses in field rheostats avoid the high losses in armature circuit resistors. Continuing the above example, reduction in speed to 25 percent can be obtained by a generator field rheostat requiring a capacity of 1,200 summation watts or by armature circuit resistors requiring a capacity of 100,000 watts.

3. Stable speeds over a wide range. A large number of speed regulating steps can be easily provided by field rheostats. The speeds will vary little with changes in load, thus the regulation is better than for many other types of speed control. In the above example, the 200 kw. generator supplying the 250 hp. motor has a drop in output voltage of 10 volts at 230 volts or about 4½ percent. At 25 percent motor speed the generator regulation would again be approximately 10 volts, which would increase to 18 percent regulation. In contrast, speed regulation by armature circuit resistance would vary from 25 percent speed at full-load to 100 percent speed at no-load. This wide speed change would be unacceptable for many uses.

4. Extremely smooth acceleration and deceleration are obtained by multi-step field rheostats that keep current and torque peaks low as the speed is changed. Even when acceleration and deceleration are done by only a few controller steps, operation is much smoother than obtained with the same number of armature resistor steps. This is because the inductance of the field winding resists sudden changes in the field flux and thus results in a more gradual increase in generator voltage and motor current. By special generator design, it is sometimes possible to eliminate all accelerators and connect the generator field to full excitation voltage in a single step.

5. Simultaneous speed control of a group of motors can be easily obtained by connecting the various motor armatures in parallel circuits to a common generator. By adjusting the generator voltage, the speeds of all the motors will change together in about the same proportion. Thus, adjustable-voltage control is particularly advantageous in controlling motors which drive individual sections of a continuous processing line, where the sections are tied together by the material being processed, such as paper, textiles, or steel. For rapid speed changes of such lines, special devices and circuits can be applied to provide WR^2 compensation for the variations in inertia of the various sections, so the sections still keep their speeds together at all times.

6. Special speed torque characteristics as required by a given machine or application can be built into the generator when it is used exclsively for one motor application. Sometimes such characteristics can best be obtained by special generator design rather than by external control means. With a separate generator thus available, adjustable-voltage control is an obvious choice. A well-known example of a special generator is the type used for operation of an electric shovel. In addition to the usual separately excited field, this generator has a self-excited shunt field and also a differential series field. This combination of fields will cause the armature output voltage to drop off rapidly as the load current increases, and thus will limit the stalled motor current and torque to a definite and predetermined value as desired for shovel operation.

Disadvantages of the adjustable-voltage control system are mainly the high initial cost of the additional rotating equipment and the stand-by losses in the idling motor generator set for a drive which operates only intermittently. The additional rotating equipment also requires its share of normal maintenance.

Acceleration Factors

If the only consideration is to accelerate a motor from standstill up to running speed, the number of accelerators can be fewer for adjustable-voltage generator field acceleration than for armature resistor step acceleration because the inductance of the field smooths out the flux changes and therefore the current and torque peaks. There are many installations where the inherent time constant of the generator field permits its connection to the full excitation voltage in a single step without any accelerating relays. There are even some large generators which have such slow build-up of the fields that instead of slowing up acceleration by means of time delay accelerators, the field is over-excited during acceleration to force the rate of acceleration.

A cumulative compound winding in the armature circuit of the generator increases the rate of acceleration and deceleration, while a differential series winding retards changes in the main field and makes the generator more sluggish in response to changes in its shunt field circuit.

Where many speed points are required, it is common practice to use face plate rheostats instead of magnetic contactors and individual resistor steps. If the rheostat is motor operated, the speed of the pilot motor thus controls the rate of acceleration and deceleration. The control sometimes uses a rheostat with more steps than are needed as speed points to keep the voltage

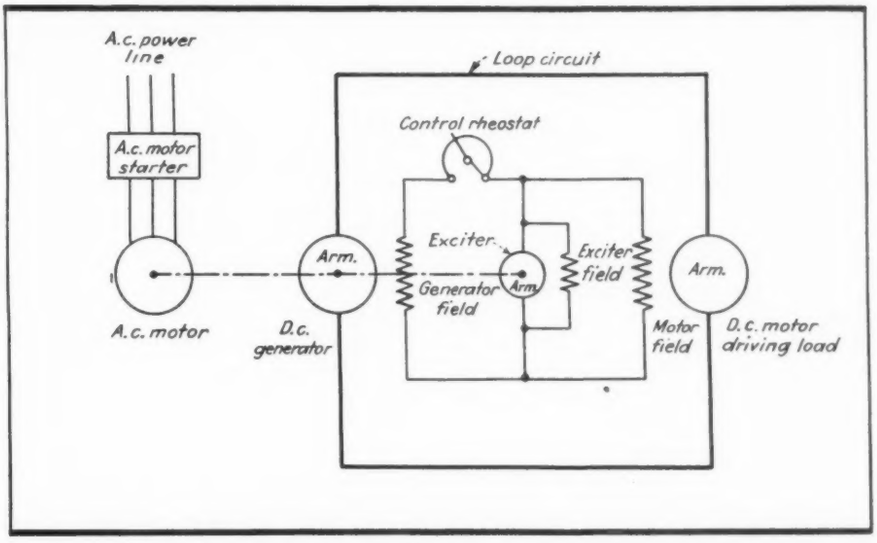
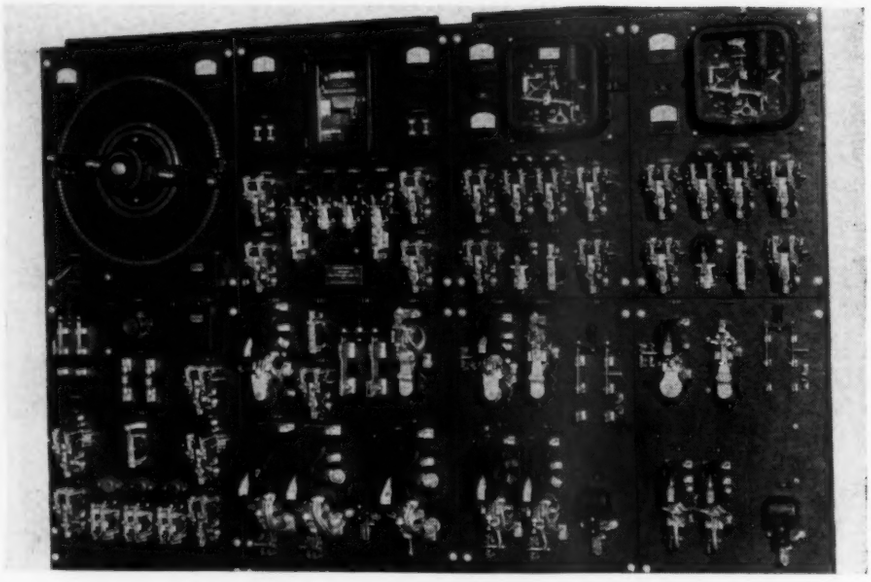


Fig. 1—Fundamental circuit for adjustable-voltage control.



Typical adjustable-voltage control for a cold strip skin pass mill.

per rheostat step below the arcing limit on sliding contacts and thus prevent rapid deterioration.

The gradual acceleration and deceleration obtained by means of motor operated rheostats are especially useful in operating a multi-motor drive. During speed changes, the sections stay together much better when many small steps are used than when only a few coarse steps are used.

Loop Circuit Considerations

If an adjustable-voltage drive is shut down by simply disconnecting the generator shunt field but leaving the motor and generator armatures permanently connected in a loop, the residual magnetism in the generator field generates a small voltage that circulates current in the low resistance loop. If the generator has a cumulative series field winding, the circulating current increases the field strength, which increases the current giving a second increase in the field strength, and so on. Such circulating currents may be greater than full load current and develop high motor torques which sometimes cause the motor and the machine to crawl even though brakes are set.

Nevertheless, for some applications it is desired to keep the loop closed for safety. For example, in elevator control the loop circuit insures that a low resistance dynamic braking circuit is always available should the brake fail. For some other applications, a contactor to open the loop would be so large and expensive that it is simpler to demagnetize the generator.

For shunt generators, sufficient demagnetization is often obtained by connecting the shunt field in reverse circuit across the generator armature, so that the residual voltage will set up a field current and flux in opposition to the residual flux. Since the residual flux destroys itself, the circuit is called a "suicide connection." The effectiveness of this arrangement depends somewhat on the generator design and can be greatly increased by using shunt fields that normally operate on half voltage.

Demagnetization is also frequently accomplished by means of separate demagnetizing fields on the generator. One effective type is a series field that carries all or part of the generator output current, and produces flux that bucks the residual flux.

When a machine has an exteremly low starting torque and no brake, to positively insure against crawling a contactor opens the loop circuit.

Electric Braking

Electric braking is often used for controlled stopping of the drive. For both dynamic braking and regenerative braking, the motor acts as a generator. In dynamic braking the generated energy is absorbed in a resistor connected across the armature. In regenerative braking the energy is returned to the power lines.

For any electric braking, whether dynamic or regenerative, it is necessary to maintain a substantial motor field while the armature is brought to standstill. With the motor stopped, the thermal capacity of the field winding on many motors is such that they cannot be left at full excitation without overheating because of the reduced ventilation. For such applications, the field current can be automatically reduced to a safe value by a field economizing relay that inserts a resistor in the field circuit.

The simplest arrangement of dynamic braking is to weaken the motor field current when the loop contactor opens and the dynamic braking starts. However, the reduction in field flux reduces the amount of braking torque that can be applied. When quicker and more precise braking is required, a control relay that operates at a present value of time, current, or voltage is used to maintain full motor field during all or most of the dynamic braking period.

The initial dynamic braking current can seldom be designed for more than 200 percent of rated current, and for a constant braking resistance the braking current will decrease as the motor slows down. Therefore, if rapid braking is required, quicker dynamic braking can be obtained by decreasing the braking resistance in a definite sequence automatically controlled by either time or current.

Regenerative braking is particularly suited to adjustable-voltage control applications and can be made to provide a very smooth and gradual slowdown by simply returning the generator field rheostat to the starting position at the desired rate. By keeping the generator voltage below the motor countervoltage during slowdown, the generator is driven as a motor and thus causes the squirrel-cage motor to return power to the lines. In many types of controllers regenerative braking can be obtained by the addition of a few simple devices. Controlled gradual slowdown is especially useful where a group of motors must keep their speeds close together during deceleration.

However, the maximum slowdown effect with regenerative braking depends upon the time constant of the generator, and also

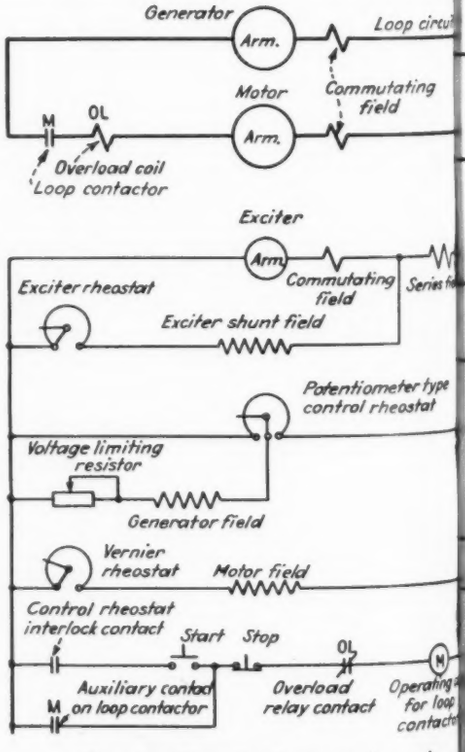


Fig. 2—Circuit diagram for adjustable speed by manual control.

the motor if motor field strengthening is involved. So for certain applications dynamic braking may be the better choice.

Five Circuit Modifications

A few simplified modifications of the fundamental adjustable-voltage control circuits will be shown and described. For simplicity the diagrams do not show the prime mover, such as the squirrel-cage motor of the motor generator set nor its starter, but only the adjustible-voltage circuits proper.

MANUAL CONTROL ADJUSTABLE SPEED. The diagram in Fig. 2 shows the generator and motor armatures connected in a loop, which includes a main contactor *M* for the loop and the actuating coil of an overload relay *OL*. The loop contactor *M* interrupts any circulating current initiated by the residual field flux in the generator that might rotate the armature of the motor. The generator field rheostat and the start and stop pushbuttons are manually operated.

The exciter supplies constant voltage d.c. for the fields of the exciter, generator, and motor, and also for the control circuits. The control rheostat in the generator field circuit is of the potentiometer type. This is often an advantage for small and medium sized machines since the field current can then more readily be reduced to low values without using extremely high resistance in the rheostat. The potentiometer type rheostat has an interlock contact that is closed only when the rheostat is in its low voltage position. The interlock contact is wired in series with the start button contact and thus insures that the loop contactor *M* can be closed only when the generator voltage is a minimum. Consequently, no separate accelerating resistor is required.

The diagram also shows a voltage limiting resistor that is usually adjusted once and for all at the time of installation, to limit the generator voltage to its rated value. Similarly, the vernier rheostat in the motor field circuit limits the field current to its rated value.

PRESET SPEED. The new feature in Fig. 3 as compared with Fig. 2 is that preset speed is obtained. The generator field control rheostat is adjusted in advance for a definite voltage and remains in this position from one operation to the next. This system provides repeated operations at the same speed without the need for adjusting the rheostat for each start of the motor. Consequently, the low voltage position interlock is neither necessary nor desired. However, it becomes necessary to provide a starter for the motor so as to gradually apply the generator voltage. A preferred method consists of a time limit accelerator *1A* which in successive steps will short circuit the accelerating steps R_1-R_2-R_3-R_4-R_5 in the generator field circuit, as shown. Another method is to leave the generator at the adjusted voltage and to use a conventional starter with resistor steps in the armature circuit. The interlocking resistor in the *M* coil circuit insures that the *1A* accelerator has its contacts open before the loop contactor can be closed.

PRESENT MINIMUM SPEED WITH HIGH TORQUE STARTING. Two new features are included in Fig. 4:

1. The minimum voltage resistor is manually set for a definite minimum speed.

2. The torque adjusting resistor and torque switch *T* provide a higher voltage for starting than is required afterwards to keep the equipment running at the minimum speed, after static friction has been overcome. When the start button in Fig. 4 is held in contact, the switch *T* is energized to open its contact, thus inserting the torque adjusting resistor as an addition to the minimum voltage resistor. Since this is part of a potentiometer control circuit, the voltage across the generator field and hence the generator voltage itself is increased as long as *T* is energized. An auxiliary contact on *T* closes the loop contactor *M* and the motor starts. When the start button is released, the torque switch drops out and reduces the generator excitation. However, when the pushbutton was initially pressed, the loop contactor established a self-holding circuit through the auxiliary contact *M* as shown, so that the motor remains connected to the generator. A timed delay can be added to the opening of the *T* contact, if

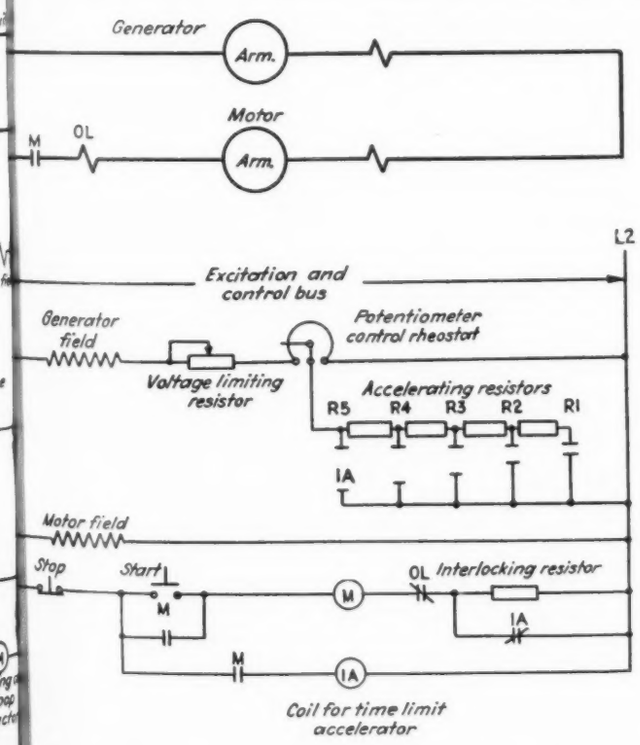


Fig. 3—Circuit diagram for preset speed control.

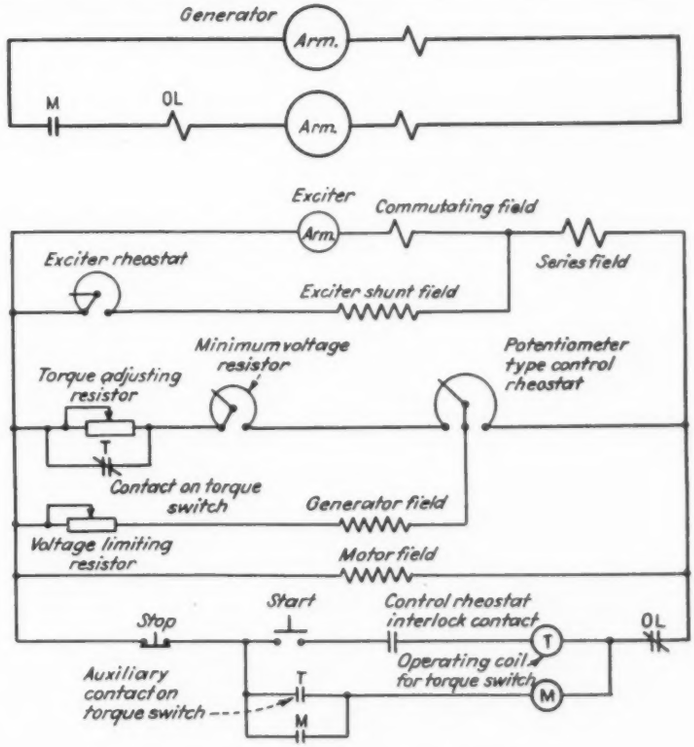


Fig. 4—Circuit diagram for preset minimum speed with high torque starting.

it is undesirable to manually maintain the pushbutton contact for the brief interval until the drive starts to move.

MOTOR OPERATED CONTROL WITH DYNAMIC BRAKING. A motor operated control rheostat is used for the generator field as shown in Fig. 5. The pilot motor for the rheostat is of a split series field type, and the rheostat has limit switches *FLS* and *SLS*, that disconnect the motor when the rheostat reaches either limit of travel. Resistors R_1-R_2 and R_2-R_3 are selected to give the pilot motor the desired speed for operation of the rheostat. As shown, the fast and slow buttons energize the appropriate pilot motor field and complete its armature circuit for the desired direction of rheostat travel. This travel takes place only while the buttons are kept in contact.

A normally closed interlock contact on the loop contactor *M* is connected in parallel circuit to the slow button and returns the rheostat to its starting position whenever the motor is stopped.

When the stop button is pressed, not only the loop contactor but also the contactor *DB* is deenergized, so that dynamic braking is applied immediately. When the jog button is operated, *DB* and *M* are energized in sequence and thus apply power to the motor. However, these contactors do not establish any self-holding circuits and drop out again as soon as the button is released, as is required for jogging operation.

To run continuously, the run button is pressed momentarily to bring in relay *CR* which maintains itself, and it in turn brings in *DB* and *M*. As shown, the control rheostat must be at the starting position before its interlock contact will close the circuit to either the jog or the run pushbutton.

MULTI-MOTOR CONTROL WITH REGENERATIVE BRAKING. A typical arrangement of a multi-motor drive is shown in Fig. 6. Two or more motors can be connected to the generator by means of a common loop contactor. In addition, certain motors may have individual disconnecting devices such as a knife switch as shown, or a magnetic contactor. For wide speed range, motor field weakening is used with adjustable armature voltage for the motor, as shown.

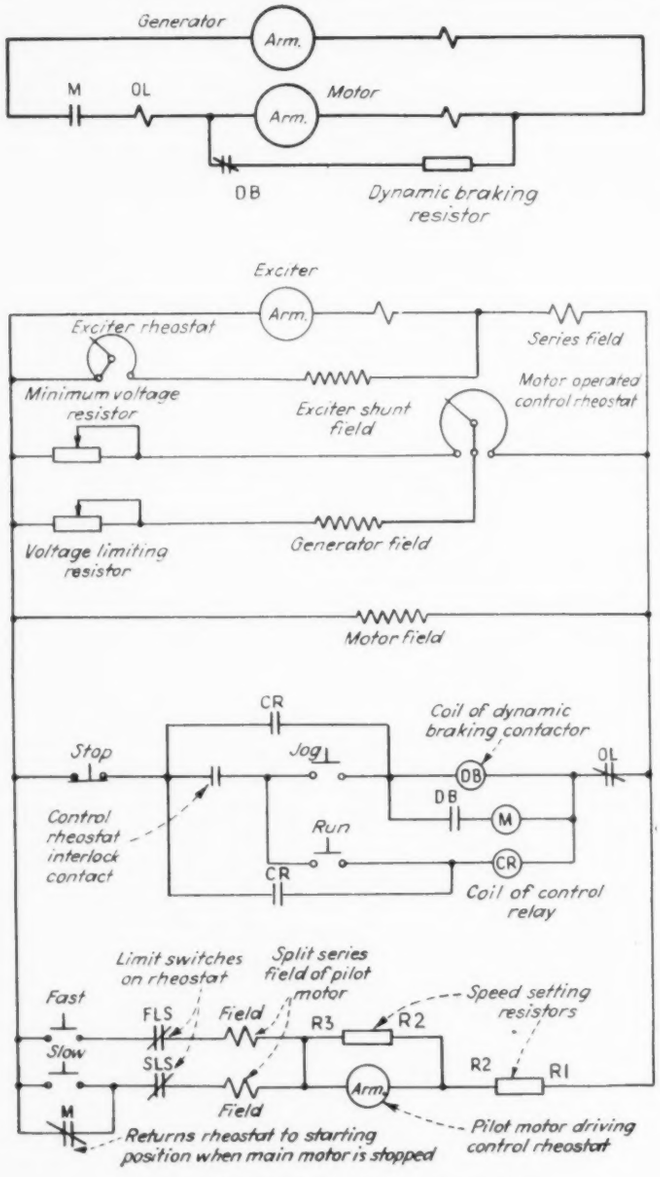


Fig. 5—Circuit diagram for motor operated control with dynamic braking.

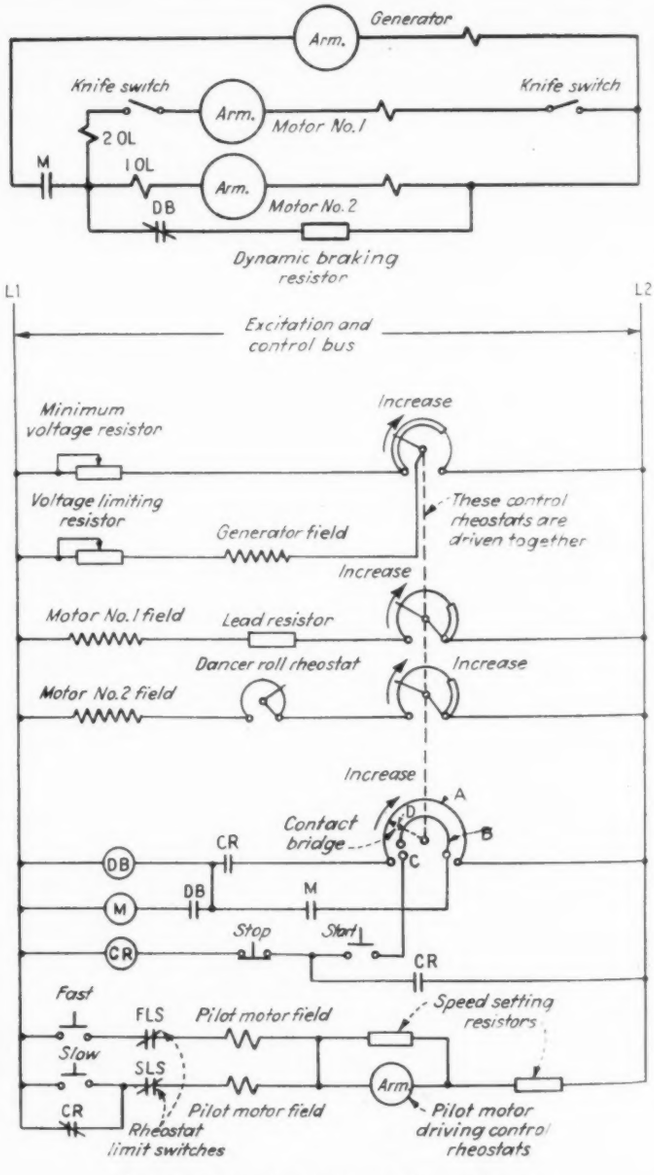


Fig. 6—Circuit diagram for multi-motor control with regenerative braking.

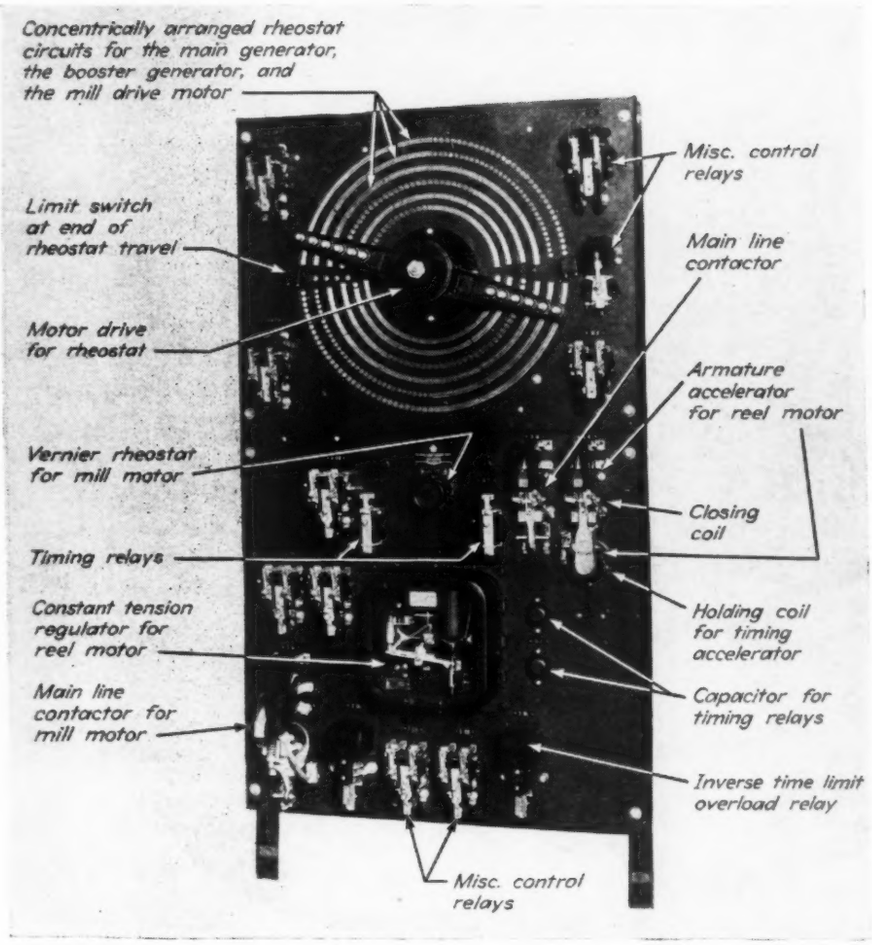

Concentrically arranged rheostat circuits for the main generator, the booster generator, and the mill drive motor
Misc. control relays
Limit switch at end of rheostat travel
Main line contactor
Motor drive for rheostat
Armature accelerator for reel motor
Vernier rheostat for mill motor
Closing coil
Timing relays
Constant tension regulator for reel motor
Holding coil for timing accelerator
Main line contactor for mill motor
Capacitor for timing relays
Inverse time limit overload relay
Misc. control relays

Fig. 7—Main control panel for an adjustable voltage mill and reel control for aluminum foil. The motor driven rheostat uses concentrically arranged circuits.

The control rheostat can have separate circuits for each field on the same rheostat face or use several separate rheostats in tandem all mechanically driven together. For maximum speed range, the rheostats are operated in the increase direction and the generator field is progressively brought to full strength, but during this part of the speed range the motor fields remain at full strength. For the balance of the rheostat travel the generator field is maintained at full strength, but the motor fields are weakened simultaneously so that the motors will speed up together with proportional increases.

If the motors are matched, that is, if they produce the same percentage speed increase for the same percentage reduction in voltage across their fields, the motor field rheostat sections may be consolidated into a single rheostat common to all motors. This simplifies the rheostat structure and avoids special resistance layouts.

In a multi-motor drive such as for continuous processing of textiles, one motor is usually selected as a speed reference. This is called the leading motor. The rest of the motors are called following motors, and some method is provided so these motors follow the speed of the leading motor. The dancer roll rheostat is a simple and effective device when the material permits the use of a dancer roll which rides in a loop of the material and operates a rheostat as the loop lengthens or shortens. To permit a dancer roll rheostat to correct in both directions from an average position, a lead resistor is ordinarily provided in the leading motor field circuit. The resistance of this resistor is equivalent to approximately one-half of that of a dancer roll rheostat.

The tandem rheostats shown in Fig. 6 include contact strips so arranged that regenerative braking is automatically obtained when the stop button is pressed. It will be noted that the usual starting position interlock for closing the loop contactor is obtained by wiring the start button to contact C, which is connected to segment A by the contact bridge D, only when the rheostats are in the proper position.

With the rheostats in the proper position, the relay CR is energized and it in turn brings in dynamic braking contactor DB and the loop contactor M. An auxiliary contact on M provides a self-holding circuit for these contactors to contact segment B of the rheostat assembly. For any speed above the very minimum, B is connected to A, that is, to L2 potential by means of the bridge D, and the pressing of the stop button will then release relay CR but not the contactors. However, a normally closed contact on CR will energize the rheostat pilot motor to return the rheostats to the starting position, thus providing smooth deceleration with regenerative braking. When the contact bridge D leaves segment B, the circuit to coils M and DB is interrupted, and M opens and disconnects all the motors from the generator. At the same time, the dynamic braking contactor DB closes its contact and applies dynamic braking for the motors as a final stage of slowdown from an extremely slow speed.

When applying dynamic braking to a processing line, it is usually important that the braking circuit be common to all the motor armatures because this helps keep the motors together and in speed during braking. Otherwise, the sections which usually have different amounts of stored kinetic energy and different loads, would slow down at different rates and stop at different times probably piling or tearing the material being processed.

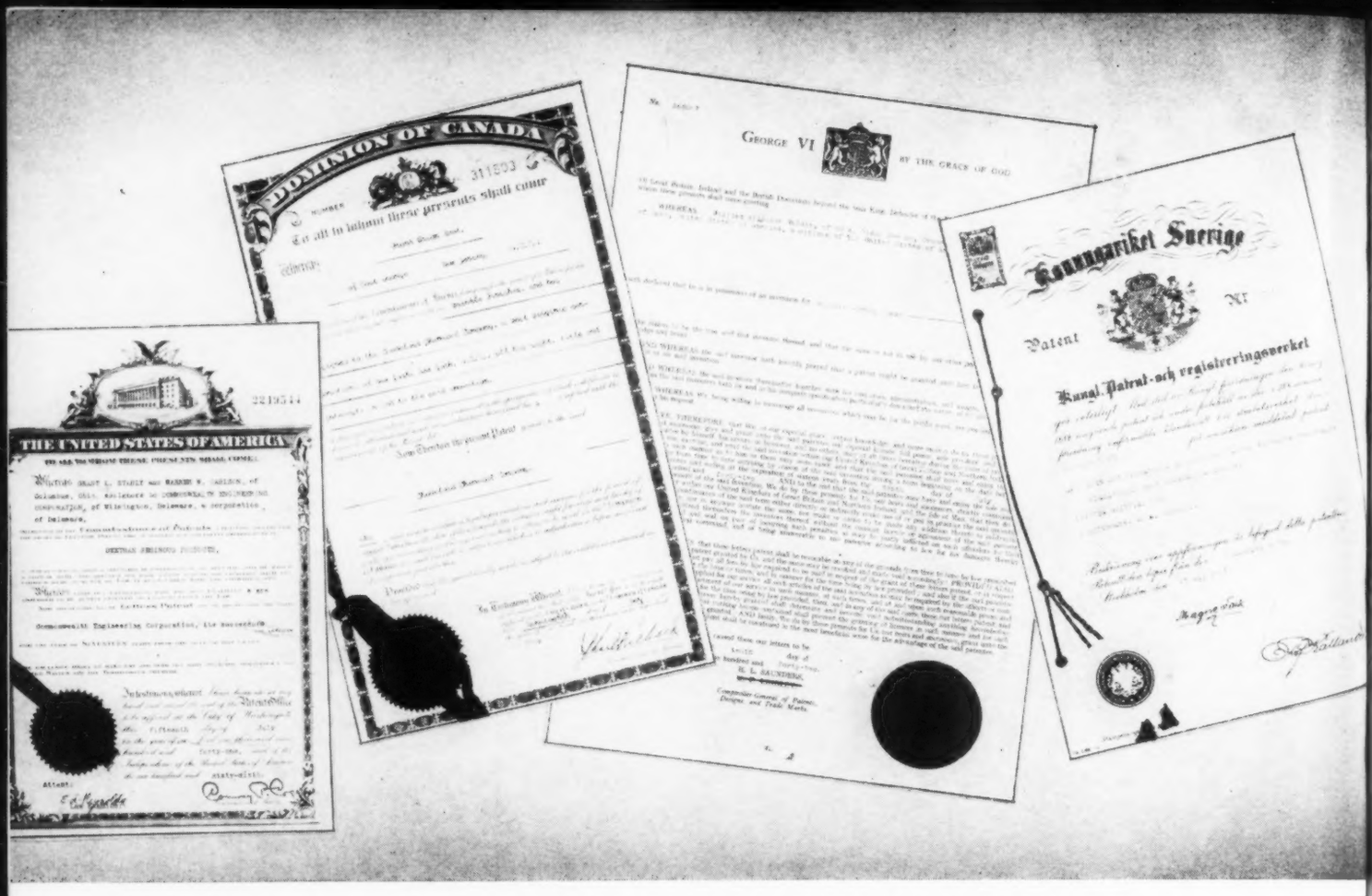
It is apparent from these examples that an almost endless variety of control combinations is available to fill the demands on performance and operating characteristics. Adjustable-voltage controllers can be very simple to suit simple needs but can also be very readily designed to provide the more complex performance required by machines and industrial processes.

German Insulation Varnish Tester

A HEAT BREAKDOWN APPARATUS for testing insulating varnish is one of several testing devices for protective coatings developed by the Germans during the war, according to a report on the German paint, lacquer, and varnish industry, made by Charles M. Jackson, an investigator for the U. S. Army.

The breakdown apparatus consists of a weighted iron disc, heated at a constant temperature of 210 degrees Centigrade and resting on a base. Two pieces of coated wire are laid at right angles between the disc and the base. The wires are connected in a series to a current source and a bell signal. If failure in insulation occurs, the circuit is broken. This causes contact between the wires and the bell rings.

Another noteworthy German development was the production of an oxidized polymerized oil from linseed oil. This product, called "Bis-Oil," was used in the manufacture of lacquer primers.



Proof that one American manufacturer obtained patent and trademark protection in four different countries: Patents for the same product in the United States, Canada, Great Britain and Sweden.

Foreign Patent Protection For American Industry

H. A. TOULMIN, JR.
Toulmin & Toulmin

THE ADVENT of peace has automatically started a new era of invention and trade. With Germany and Japan removed as some of the greatest manufacturers of industrial products, America will again have to take the lead—this time by means of international trade—to replenish the continents depleted of all kinds of goods by six years of devastating war.

This obligation, however, also affords an unparalleled opportunity to build up foreign markets. Such foreign markets will not only be able to take up any possible slack on the domestic market but will also materially help research and development work.

The average American manufacturer is conscious of these facts and he will be concerned about the protection of his products against unfair competition abroad. He will, therefore, ask himself these critical questions: "What is the value of foreign patents and trademarks?" and "Which of my products should be protected abroad?"

The answer to these questions will be somewhat different for each country. It may generally be said, in answer to the first question that most foreign countries in which private enterprise and competition prevail have well established patent offices, and their patent and trademark laws give reasonable protection against patent infringement or unfair competition. The announcement of a new patent or trademark in the official patent publications of foreign patent offices often arouses the interest of businessmen in these countries, with the result that new markets for the product are opened up.

As to the second question concerning products to be protected abroad, it may be said that as a rule inventions of minor importance should not be protected abroad unless they fit into a general plan of overall protection in an industry which the interested manufacturer has already established abroad.

Generally foreign patent protection should be limited to the more important inventions. Particularly important in this connection are all kinds of American business machines and devices which will facilitate the performing of business operations, and also all kinds of work facilitating domestic appliances. All progressive labor-saving devices and processes as well as machine tools and productive machines which cheapen the cost of manufacture are of particular interest.

Europe is practically depleted of this type of machinery because Germany's wartime government confiscated all machine tools in the invaded countries and took them to Germany where they were later destroyed by Allied air attacks. Other countries outside of the United States that were not invaded were unable during the

war to replace their machinery and to get the necessary lubricating means therefore. The result is old, wornout machinery or none at all.

Some other countries like Australia are trying to acquire a part of the former Japanese market but before they can do this they will have to expand their industry. Therefore, Australia should be a good market for most of American industrial products.

Patent protection in England, Canada, Australia and other British dominions has the two-fold advantage of not only protecting the exported goods of the manufacturer but also of obtaining a market under preferential tariff conditions. For this reason, American concerns have located manufacturing plants in these countries, thus obtaining the benefit of preferential tariffs granted to dominions of the British Empire.

Also of great interest for the export market are all types of optical and chemical products which before the war were to a great extent supplied by Germany.

To meet competition in the world market it is often advantageous to obtain a patent in that foreign country where the respective product is being made and from where it is shipped to foreign countries. In this way the competition will be met either at the source of arrangements may be made which will reduce competition to a sound level.

The vital questions to be taken into consideration in establishing a foreign patent policy are these:

1. What are the primary markets of the world in which competitive manufacturing will take place, those in which competitive selling will take place, and those from which exports will arise to create competition in foreign trade or in the United States? Patent protection should be directed primarily to those exports where competition is keenest or where manufacturing takes place in competitive surroundings.

2. What manufacturers in foreign countries own competitive patent rights in the United States for which the manufacturer may trade his patent rights in the other competitor's country? Such competitiors would thus find it desirable to exchange information in return for rights under foreign patents in their own country.

3. What manufacturers abroad can be licensed in order to control their competition? Should royalties be received. This would not only help them control their prices, but would lead to an exchange of ideas and technical information for further research and development in the United States as well as abroad.

The answers to these critical questions will determine what products and processes are to be protected abroad, and in what countries the protection is to be effective.

A valuable point to remember is that it is possible under foreign laws to combine certain American patent applications, which have to be separated in the United States Patent Office, but which abroad can be filed as a combined unit thereby greatly reducing the cost.

Once established in the foreign market the American manufacturer will, because of his foreign patents be able to protect himself against unfair competition. In this connection the importance of foreign trademarks should not be overlooked.

Many countries before entering the trademark of the foreign applicant require proof that he has registered his trademark in his own country. To furnish this proof, a certified copy of the home registration has to be presented. The foreign registration corresponds in general to the home registration both as to the outward appearance of the trademark and the specification of the product for which the trademark has been registered.

Great danger lies in the practice of foreign registration of the trademark by an American manufacturer's foreign agents or his competiting foreign agents. One of the most frequent piracies of American trademarks is committed by the foreign selling agents or the representatives of American companies. In this connection the United States Department of Commerce "Commerce Reports" of April 21, 1930 in which is stated the following:

"The American exporter in the early stages of establishing a market abroad, in fact, is seldom aware that his foreign agent, with whom his general business relations are most satisfactory, may be inclined to register a trade-mark in his own name, with a view to the continuance of the agency, with the intent later to require his principal to purchase the rights in the mark, or, as not infrequently happens, for the protection of the principal himself.

"While the agent's motive or intent may not always be improper, and often it has been found that such registrations are made in good faith, even in such instances difficulties often arise when the principal requests an assignment or transfer to the trade-mark. Regardless of the motive that prompts the agent, he has a decided advantage, since the property right in the trade-mark is in his name. Nor is the agent always to blame, since it is an indication that the principal has failed to use proper diligence to protect his property rights."

In many countries, particularly the Latin American countries, only he who registers the trademark is the sole owner irrespective of whether or not he originated the trademark. It is, therefore, possible that in a foreign country in which the American owner of a trademark failed to register his trademark, a native or competitor may register it. In many instances the registrant will have then the right to confiscate your goods bearing your trademark when it arrives in that country.

This actually has happened to quite a number of United States concerns who failed to register their foreign trademarks in advance of shipping into foreign countries. The registration of foreign trademarks is, therefore, an important insurance policy as has been well recognized by the United States Department of Commerce which stated in the "Commerce Reports" for December 8, 1930:

"That it is necessary to protect the legal right and little in the trade-mark, or other means of identifying products sold by American exporters in foreign markets—especially because of the tendency to simulate American goods abroad—it is quite generally known to most American exporters. The shipper of American goods destined for consumption in foreign lands has learned the advisability of registering his trademarks and labels in accordance with the provisions of the trademark laws of those countries in which the markets are located."

Those executives whose companies are engaged in international trade, or who are planning to do so, should ask themselves these essential questions, the answers to which will furnish the basis for sound policy in protecting their trademarks and good will overseas.

Question 1: What are my plans for world trade, that is, into what countries will I ultimately export, through what channels, and by what type of agencies?

Question 2: What control will I have over my goods both in the ports of embarkation and after they enter a particular country in order to protect the trademarks on them, and the good will of my concern?

Question 3: What are the religious, social and political prejudices that my trademarks must satisfy? Shall I protect it in black and white and also in color?

Question 4: What are the packages, labels, and containers that I will use and how will they be marked with my name, trademark, and other identifying information?

The fundamental lesson of all trademark experience abroad is that no single step is of greater value to a corporation than the protection of its trademark rights overseas. Trademarks that can be identified through some well-known symbol even though the American name is unpronounceable and means nothing to the vast body of illiterates who may purchase the goods. The color may have a special religious or social significance which may either meet with approval or be violently prejudicial in certain countries, so that the goods carrying a trademark with that particular color will not sell at all.

Trademarks and patents go together. A product that is protected both by patents and trademarks is in a far stronger position than one protected by either patents or trademarks. It is this teamwork that insures success in overseas merchandising, and the protection of both the product, the good will and the name of the merchandiser.

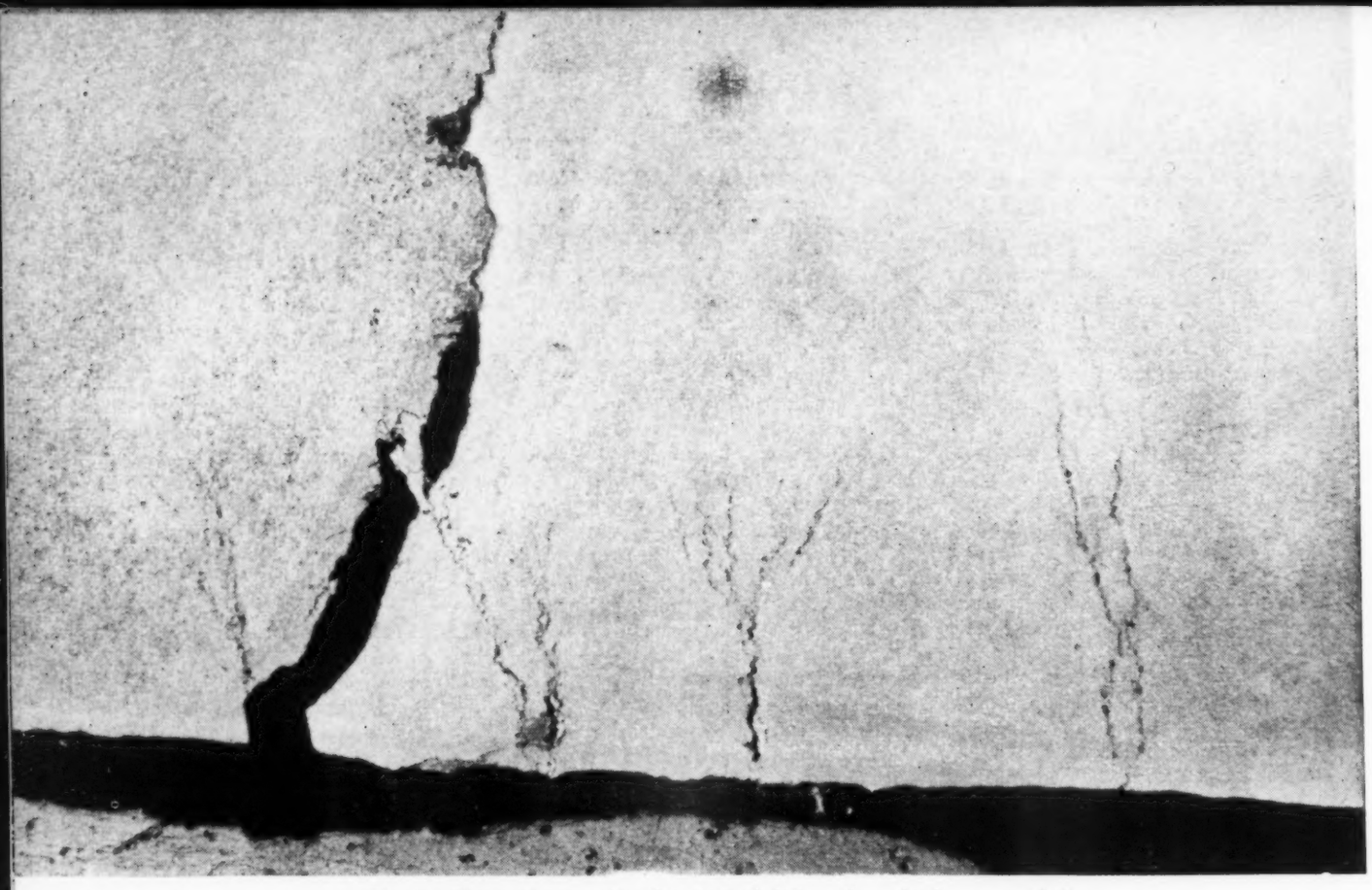


Fig. 1—Photomicrograph of a typical failure from hydrogen embrittlement, which spreads tree-like in all directions through the specimen.

Lockwasher Breakage Resulting From Hydrogen Embrittlement

WALTER L. FLEISCHMANN
General Electric Company

Simple test procedures and methods of preventing failures. Progressive failure, typical of hydrogen embrittlement, is described and illustrated. Information for specifications is included as well as precautions to be observed in manufacture.

INVESTIGATIONS of lockwasher breakage reveal that hydrogen embrittlement is a cause of failure. Breakage occurs oftener in plated parts, especially parts that have been protected against corrosion by plating or other processes.

The term "hydrogen embrittlement" denotes in this discussion the embrittlement of steel caused by hydrogen that is absorbed during the operations of heat-treating and acid pickling, as the result of corrosion, and during the process of plating, in which the so-called cathodic hydrogen is liberated. The hydrogen that is absorbed during melting of the steel and afterwards becomes occluded gas in the solidified metal is not a significant cause of failure in the type of service discussed here.

Hydrogen embrittlement makes itself apparent as a brittle break with little or greatly diminished plastic deformation, even under light loading. The progressive, tree-like failure from hydrogen embrittlement, illustrated in Fig. 1 to 3, is unlike the break caused by excessive static loads. Under static loading failure occurs at right angles to the maximum stress and across the grains. A typical failure from hydrogen embrittlement spreads in all directions, often following irregular grain boundaries.

Since the lockwasher is merely one element of a bolted connection, its utility depends upon the other members of the combination. Any discussion would be incomplete without some consideration of the functions of these other members; hence

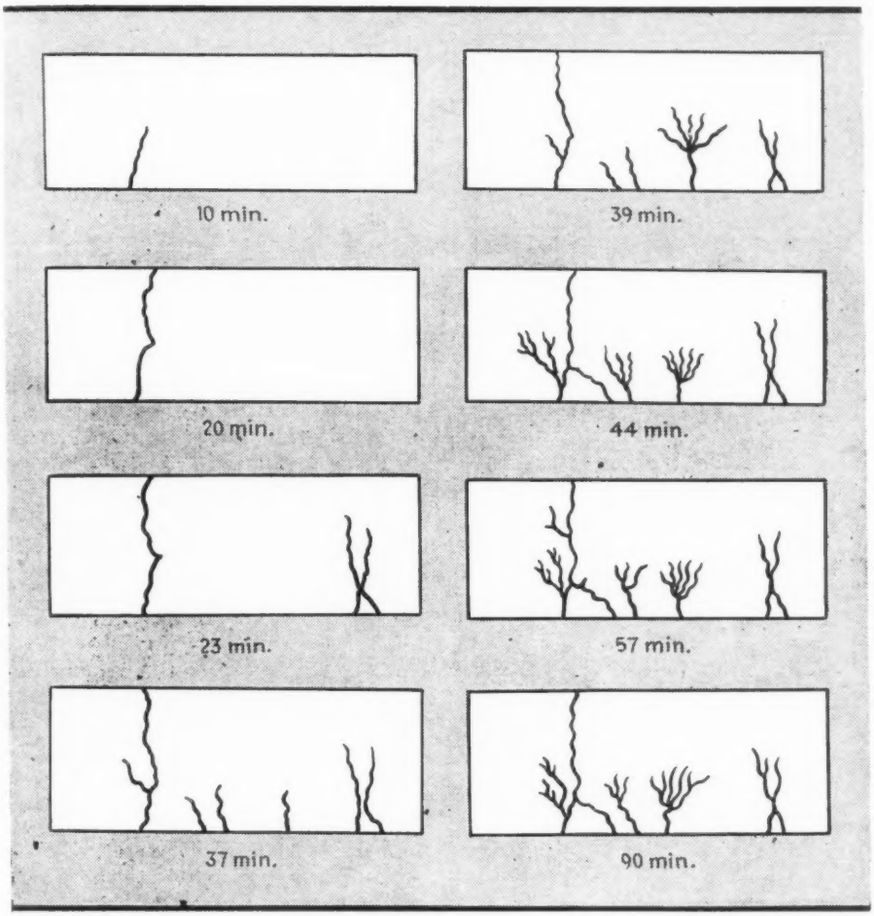


Fig. 2—Sketches as observed through a microscope showing the manner in which the failure started and spread through the specimen of Fig. 1 until breakage occurred. Failures like this can be duplicated in hardened steel test washers.

the next few paragraphs review some of the fundamentals of the bolted connection.

Basically the requirements of a bolted connection are (1) to maintain its tension and stay tight, and (2) to be easily assembled and disassembled. The tension within the bolt is obtained by an applied torque, but the applied torque is not a reliable measure of the magnitude of the tension. Frictional losses in the threads and frictional losses between the base of the nut and the abutting surface vary over wide ranges. The use of a hardened spring lockwasher between a steel nut and an abutting surface of soft metal, such as copper, will reduce the frictional losses.

Getting the proper bolt tension warrants engineering attention, in particular because a permanent connection cannot be obtained if the bolt is not put initially under sufficient tension. The only accurate way of measuring bolt tension is to measure the elongation of the bolt. This is not generally recognized, although standard practice for years has been to tighten bolts in flanges on high pressure steam lines and on turbine flanges according to measured elongations.

Maintaining the bolt tension means keeping the bolt constantly elongated. This is easier done on long bolts than on short ones. Compression and wear of the bolted members, whether they be thick or thin, often are nearly equal in magnitude; consequently the percent loss of total elongation and tension for the long bolt is proportionately smaller than that for the short bolt. In heavy machinery, the effective bolt length is sometimes increased by introducing a length of tubing having an elasticity equivalent to that of the bolt. A lockwasher that would support a load comparable to the working stress of the bolt would be the ideal.

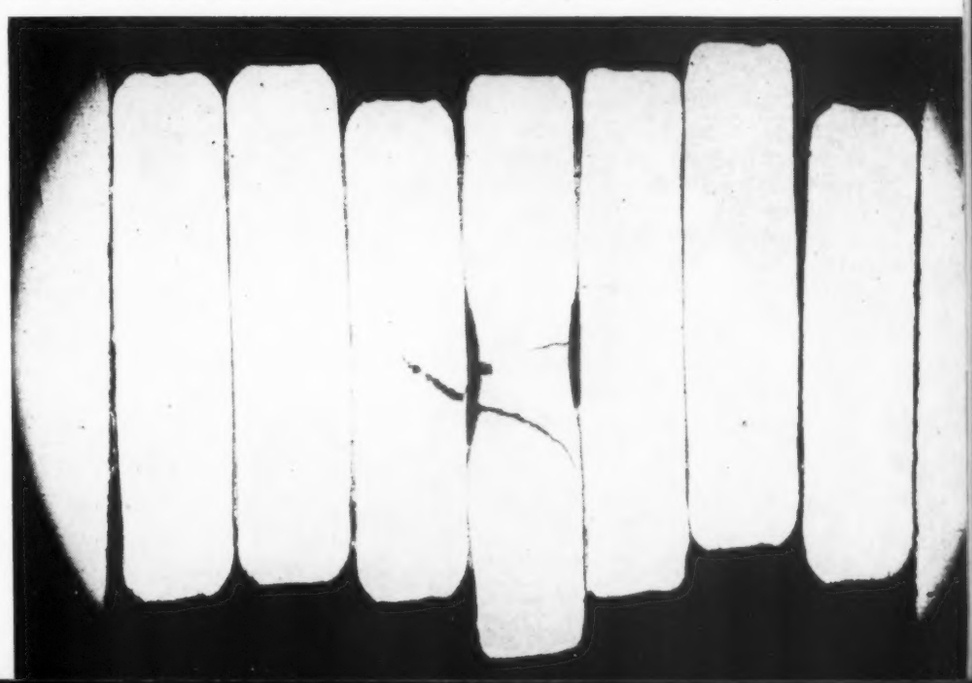
Tests conducted by an automobile manufacturer show that a hardened flat washer is just as effective in many applications as a spring washer. On the contrary, the cost of a hardened flat washer is many times that of the widely used spring washer, which is coiled from wire. Wherever the spring-type washer is specified on drawings expressly to reduce friction, washers with pointed or rough surfaces should be avoided.

Tooth type washers also are widely used. They are so designated that, upon compression, the teeth are elastically twisted and follow a slight movement. The spring action of the teeth depends upon the hardnesses of the surfaced between which they are compressed. If the surfaces are soft, the teeth act as interference to rotation. Between hard surfaces, they act as a spring until stressed beyond the yield point.

Material for a lockwasher is chosen on the same basis that material is selected for a spring; namely that a considerable force has to be stored in a small volume of metal. The elastically strongest material is preferred for lockwashers. Thus a steel with a high ratio of yield strength to tensile strength, plus sufficient ductility, is more generally used than the so-called noncorrodible alloys, which have low yield strength, softness, and low modulus. The latter, on the other hand, are better suited to eliminate freezing by corrosion of the head or nut against the abutment.

A carbon steel of 0.60 percent C is widely used. Heat-treatment takes place in rotating drums or shake-type furnaces through which a cracked gas atmosphere flows to prevent decarburization. The lockwashers are oil quenched at 1,450 to 1,500 deg. F. and, as they are still too brittle, they

Fig. 3—Several lockwashers under test for hydrogen embrittlement and a typical failure of one of them. A failure in 72 hr. is likely to be followed by others.



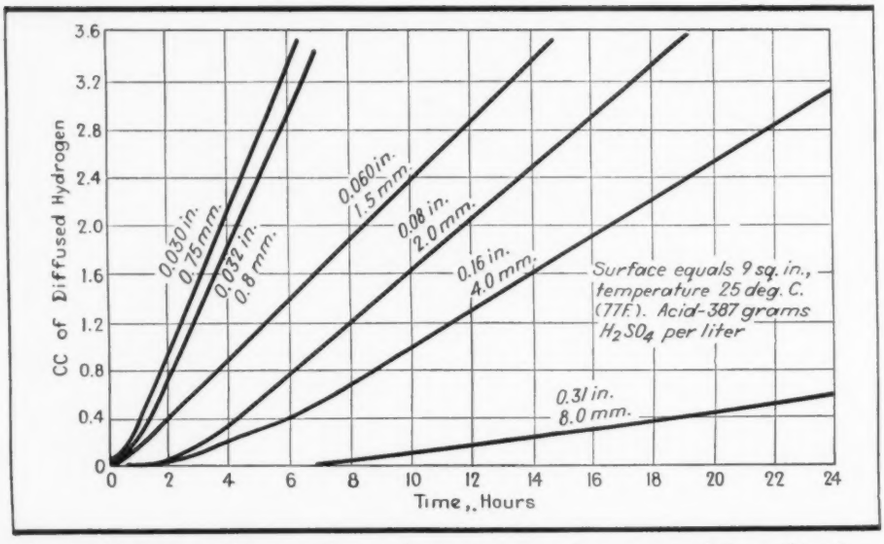

CC of Diffused Hydrogen
Time, Hours
0.030 in. 0.75 mm.
0.032 in. 0.8 mm.
0.060 in. 1.5 mm.
0.08 in. 2.0 mm.
0.16 in. 4.0 mm.
0.31 in. 8.0 mm.
Surface equals 9 sq. in., temperature 25 deg. C. (77F). Acid-387 grams H_2SO_4 per liter

Fig. 4—Hydrogen diffusion during plating is so much more rapid from thin than from thick sheet that thin lockwashers seldom fail from hydrogen embrittlement.

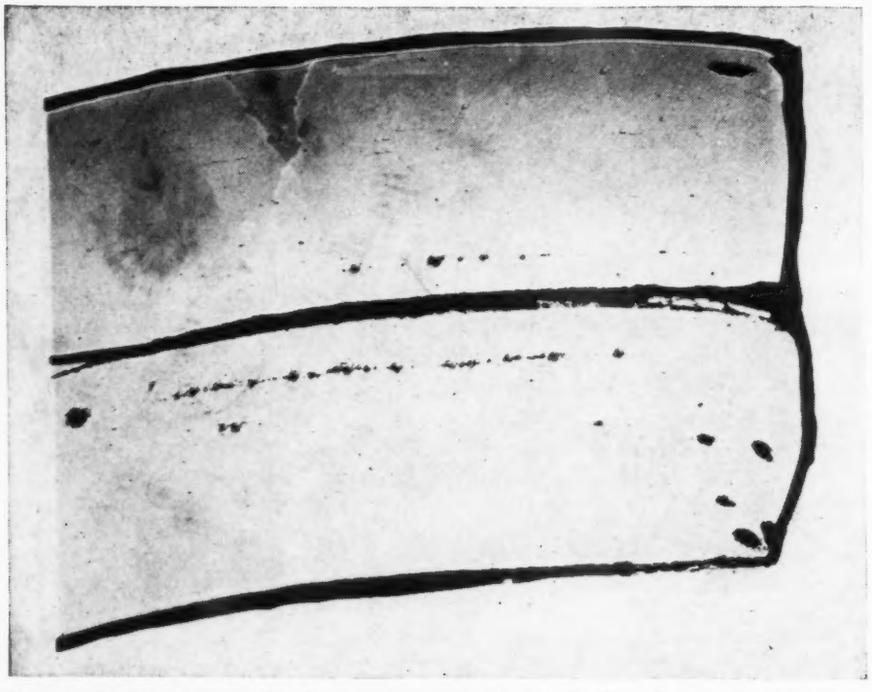


Fig. 5—Photomicrograph of a steel sample that is badly affected by hydrogen embrittlement because of dirt in the steel. 100x mag.

are tempered to a hardness of 48 to 52 Brinnel. The heat-treating operation rarely supplies some hydrogen toward hydrogen embrittlement. Subsequent processes, such as acid pickling, corrosion, plating or any process causing the decomposition of water, are other sources of hydrogen.

Tests for Hydrogen Embrittlement

A simple, short-time test for hydrogen embrittlement can be made by bending a lockwasher between two pliers. The failure will occur abruptly without any yielding, and the break will appear shiny if the metal has been impaired by hydrogen embrittlement.

A longer test, which is more reliable for acceptance purposes, consists of clamping about twenty washers between plates and holding them compressed for 72 hours. If none of the washers fails during that time, the lot can be considered reasonably free from hydrogen embrittlement. One failure is a good indication that more failures will occur if the washers are kept compressed for a longer period.

In electrolysis, atomic hydrogen is deposited on the cathode. The hydrogen catalyzes from $2H$ to H_2 and escapes as hydrogen gas. The rapidity with which the catalytic reaction takes place affects the rate of hydrogen absorption by the base metal. The amount of hydrogen absorbed depends on the type of metal and, what is not generally recognized, also upon the impurities on the metallic surface.

Acid pickling is a prolific source of atomic hydrogen, more so than corrosion and plating. Moreover the effects of the absorbed hydrogen make themselves felt long after the pickling processes. The only sure cure is to avoid pickling. For this reason specifications for lockwashers usually do not allow acid pickling or acid cleaning, even a short dip prior to plating.

In general, less hydrogen is absorbed during plating than during acid pickling. The amount absorbed is influenced by impurities both in the plating bath and in the steel. Tin as an impurity in steel and other elements, such as selenium, tellurium, arsenic, sulfur and phosphorus, prevent cathodic hydrogen from forming into molecular hydrogen. Soluble impurities build up faster in zinc plating baths than in baths for cadmium plating, which is a plausible explanation as to why more zinc plated washers than cadmium plated washers failed during test because of hydrogen embrittlement.

Thin washers rarely absorb enough hydrogen during plating to suffer from hydrogen embrittlement. This is attributed to the faster rate of diffusion or liberation of hydrogen from the thinner pieces. The curves of Fig 4 show the degree to which thickness influences the rate of diffusion.

Internal voids and nonmetallic inclusions not only weaken the lockwasher as a structural member but also serve as loci for molecular hydrogen accumulation. Hydrogen embrittlement frequently is associated with such spaces in which pressure is exerted by the formation of gas.

Hydrogen embrittlement is avoided by removal of the hydrogen. If hydrogen gas escapes freely during plating, hydrogen embrittlement is unlikely. Baking is the accepted method of removing hydrogen from finished parts. The higher the baking temperature, the more rapidly and completely is the hydrogen driven off.

A controversial issue is the time that can be allowed to elapse between the plating and baking processes. Undoubtedly the same quantity of hydrogen, if still present, will be liberated at the same temperature per unit time from equal thicknesses, no matter whether two, three or eight hours have passed between plating and baking. On the other hand, so long as the hydrogen concentration remains in the steel, ruptures in small areas caused by the pressure may be taking place. Baking at a later time will not heal these discontinuities. Thus a failure apparently from hydrogen embrittlement is actually an after-effect of hydrogen embrittlement.

NEW BOOKS

Modern Plastics Encyclopedia

Published by Plastics Catalog Corp., 122 E. 42nd St., New York 17, N. Y. 1,389 pages, 8½ x 11½ in., white clothboard covers. Price $6.

This is the 1946 edition of what was formerly the "Plastics Catalog." This valuable reference book is an informative and authoritative source of data on all types of plastic materials and processes, and will prove useful to engineers interested in plastics. Each type of plastic material is covered in a separate chapter which details manufacture, forms available, methods of fabrication, equipment and machinery necessary and typical applications. Extensive information on the chemistry of plastics is included. Particularly useful are the charts on identification, properties, S.P.I. classification of molding materials, chemical formulas, manufacture, plasticizers, solvents, adhesives, coatings and synthetic rubber—printed on separate sheets, so that they can be used with any portion of the text.

The section on engineering design is particularly well presented. Included are chapters on plastics product design, types of molds, construction of molds, and plastic models as industrial design aids. The materials section has been brought up to date by the addition of newly-developed materials.

Treatise on Thermodynamics

MAX PLANCK. *297 pages, 5½ x 8½ in., black clothboard covers. Published by Dover Publications, 1780 Broadway, New York 19, N. Y. Price $2.75.*

This is the third revised edition of the famous work by the Nobel prize winner and founder of quantum theory. Translated from the German by Alexander Ogg, professor of physics at the University of Capetown, South Africa, this treatise has long been considered the most profound treatment of the subject. Planck's treatment of thermodynamics does not advance any mechanical theories of heat nor does it start with definite assumptions as to its nature. Instead, it employs an inductive treatment, starting from a few general empirical facts, mainly the fundamental principles of thermodynamics. By purely logical reasoning, a large number of physical and chemical laws are derived. These, as the intervening years have proved, are capable of extensive application.

1946 ASHVE Guide

Prepared and published by the American Society of Heating and Ventilating Engineers, 51 Madison Ave., New York, N. Y. 6 x 9 in., blue cloth covers, 904 pages. Price $6.00.

The technical text contains fifty-one chapters grouped under the general section headings of Principles, Human Reaction to Atmospheric Environment, Heating and Cooling Loads, Combustion and Consumption of Fuels, Heating Systems and Equipment, Air Conditioning, Special Applications, and Installation and Testing Codes. New chapters have been added on fluid flow and operating costs. A comprehensive listing of codes for testing, rating, selecting, and installing heating, ventilating, and air conditioning equipment has been added to the Codes and Standards sections. Material from Society sponsored research on air flow in outlets has been added together with an air friction chart based on studies made at the ASHVE Research Laboratory. Air contaminants are defined and treated in a separate chapter, which contains tables showing maximum allowable concentrations of contaminants in space used for human occupancy.

Plastics Mold Engineering

J. H. DUBOIS AND W. I. PRIBBLE. *494 pages, 5½ x 8½ in., brown clothboard covers. Published by American Technical Society, Chicago, Ill. Price $7.00.*

Many tool makers have considered their mold-making practices a trade secret, and little has been published on this subject. This lack of available information has been an important loss to the plastics industry, which has been striving for increased precision in product design. Mr. DuBois, executive engineer of the Shaw Insulator Company, makes an important contribution to the engineering of plastics with the publication of this book, which describes the design, use, construction and fabrication of the important types of molds.

Of special importance to design engineers is the chapter on plastics product design. Subjects covered in this chapter are material selection, moldability, parting lines, knockout pins, pickups, shrinkage, dimensional tolerances, warpage, draft, wall thickness, fillets, sharp outside corners, ribs and bosses, holes, molded threads, inserts, lettering on molded products, surface finishes and machining molded plastics.

Recommended Practices for Resistance Welding

Prepared by the A.W.S. Resistance Welding Committee. 6x9 in., gray paper covers. Published by the American Welding Society, New York, 18, N. Y. 50 cents.

A compilation of recommended practices for the spot and seam welding of low-carbon, stainless and hardenable steels, nickel monel and inconel; the projection welding of low-carbon and stainless steels; flash-butt welding of low and medium forging strength steels; and standard methods for testing resistance welds. Each recommended practice comprises a table of machine settings for current, voltage, time, and pressure which will produce welds of specified strength in various thicknesses of materials. The section on standard methods for testing resistance welds covers tests for tensile properties, shear strength, impact strength, fatigue properties and hardness and includes descriptions of the test specimens, the equipment used and the procedure followed.

Rubber in Engineering

Prepared under the direction of the Controller of Chemical Research of the Ministry of Supply and the Directors of Scientific Research of the Ministry of Aircraft Production and the Admiralty on the basis of research carried out by the Imperial Chemical Industries, Ltd. 267 pages, 5½ x 8½ in., gray clothbound covers. Published by Chemical Publishing Co., Inc., Brooklyn, New York. Price $5.50.

A general survey of the fundamental properties of rubber with the problems arising in the manufacture and use of rubber articles discussed in detail. Theoretical and practical data are presented to demonstrate how variables, such as heat, abrasion, exposure, and fatigue, affect the behavior of rubber. Tabular and graphical material is used profusely throughout the book.

The Metallurgy of Steel Castings

CHARLES WILLERS BRIGGS. *634 pages, 6 x 9 in., black clothboard covers. Published by the McGraw-Hill Book Co., 330 W. 42nd St., New York 18, N. Y. Price $6.50.*

A single source reference on technical and metallurgical control in the production of steel castings. All manufacturing operations for the production of steel castings are considered. The subject of mold design and the effects of molten steel on sands, cores, and washes are dealt with in detail together with the subsequent cleaning, chipping and grinding and heat-treatment of the as-cast steel. In addition, related subjects such as gases, deoxidation and inclusions, and the properties of liquid cast steel are included.

Luminous Tube Lighting

H. A. MILLER. *142 pages, 5½ x 8½ in., blue clothboard covers. Published by the Chemical Publishing Co., Inc., Brooklyn 2, N. Y. Price $3.50.*

This text presents the fundamental theory of gaseous ionization and light production, and lists the materials and their required properties for use in luminous tubes. The various manufacturing processes in developing low-pressure and high-pressure luminous tubes, both of the low and high voltage types are discussed. Each type of luminous tube; the mercury and sodium discharge lamps, fluorescent lamps and neon tubes, is dealt with from the standpoint of construction and operation.

Mechanical Packings Manual

Prepared and published by the Graton and Knight Co., Worcester 4, Mass. 6 in. x 8½ in. brown flexible leather cover. Price $4.50.

A handbook on the selection of mechanical packings types, their application, and the design of adjacent parts in hydraulic or pneumatic equipment. The basic principles that influence packings life and resultant machine performance are outlined. Both leather and synthetic rubber packings are discussed and operating conditions governing the selection of material are included. The book is adequately indexed.

Stranded Wire Helical Springs For Machine Guns

H. H. CLARK
Eaton Manufacturing Company

Comparison of spring characteristics and life expectancy with the corresponding properties of conventional helical springs. The effect of number of strands on spring design, deflection, damping and resonance are discussed. Methods of testing, interpretation of test data and observations during manufacture of satisfactory springs are considered.

HELICAL SPRINGS formed of a strand of three wires twisted together were first observed in Russian machine guns used in the Spanish Civil War. The stranded spring performed for from three to five times as many rounds as single wire springs.

When an axial load is applied at the ends of a stranded helical spring, the material forming the helix is subject to a twisting moment. In this respect the stranded spring is not essentially different from a conventional helical spring made from a single homogeneous wire. The outstanding characteristic of the stranded spring is an inherent tendency for the damping of high velocity displacement of its coils.

In the stranded spring it is essential that the helix of the strand be opposite in direction to that of the coils of the spring. As indicated in Fig. 1(A), if the strand has a left-hand twist and the spring is coiled right-hand, the twisting moment of an applied axial load tends to cause a wind-up or angular deflection of each helically formed wire much in the same manner as though it were a high-pitched torsion or rat-trap spring. The wires of the strand are in contact with each other even in the unloaded state; and, since there can be no appreciable wind-up, binding between the wires results. If both the strand and the coils of the spring have the same turn of helix, as shown in Fig. 1(*B*), the twisting moment tends to unwind the strand. Not only is the binding action lost, but also the spring deflects as though it had a subnormal value of shear modulus.

For load-deflection computations the stranded wire spring may be resolved into as many partial springs acting in parallel as there are wires in the strand. Where K is a factor, n is number of wires in the strand, G is shear modulus, d is diameter of wire in the strand, D is pitch diameter of spring coils, and N is number of active coils, the rate of deflection R can be determined by

$$R = Kn\frac{Gd^4}{8D^3N} \qquad (1)$$

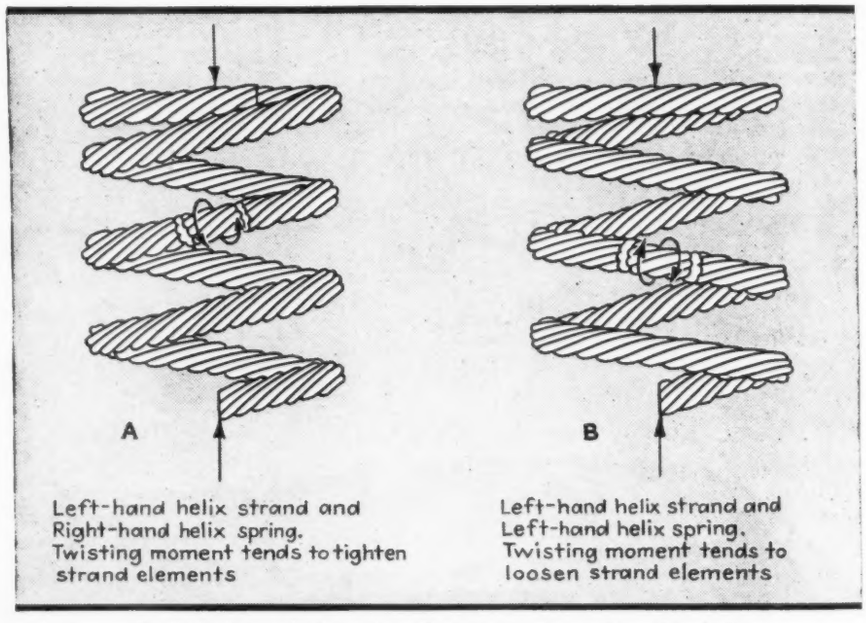


Fig. 1—Stranded spring design requires that the helix of the strand be opposed in direction to that of the coils.

For three-wire strands a value of about 1.05 is suitable for the factor K. For steel springs the shear modulus G is 11.5×10^6 lb. per sq. in. Stranded springs usually have one coil closed at each end, but the ends cannot be closed as effectively as they can in conventional springs. The end coils of stranded springs are not usually ground except for a snagging operation to remove the sharp edges where the strand has been cut. For such end construction the total number of coils less 1.2 can be taken as the number of active coils.

It is safe to assume that the principal stress to be considered in stranded springs is the shear stress produced in the component wires by the twisting moment, which is a function of the applied axial load. The true maximum value of the shear stress under static conditions is affected by the curvature of the wire in regard to both the radius of the helix of the coils and the radius of the helix of the strand, by the degree of prestressing received by the spring in the pressing operation during manufacture, and by the compression in the wires in consequence of the binding action inherent in the stranded spring.

An accurate computation of the numerical values of the shear stress in the stranded spring is therefore difficult. If the spring is resolved into partial springs acting in parallel, as is assumed for load deflection computations, and f is the deflection of the spring, an average value of the shear stress S can be obtained for each partial spring from

$$S = \frac{Gdf}{D^2N} \qquad (2)$$

Because of wave motion caused by the high velocity of displacement of the coils of a driving spring in operation in a gun, the maximum dynamic stresses are gen-

erally higher than the computed stresses in the spring when deflected statically to solid height. For a given application it often develops that driving springs, which have relatively low values of statically computed stress at solid compression, fail earlier than springs in which the stress at solid compression is relatively high. Performance of driving springs cannot be predicted by stress computations for static assumptions.

The average stresses at solid compression in the stranded driving springs made to date range from 150,000 to 170,000 lb. per sq. in. for music wire about 0.070 in. in dia. to from 170,000 to 195,000 lb. per sq. in. for wire about 0.030 in. in dia. These stress values at solid compression can be exceeded by as much as 10 percent by resorting to a greater degree of prestressing during manufacture.

Neglecting the effect of a difference in end-coil construction and in the number of inactive coils, it can be demonstrated that a three-wire stranded spring, having wire diameters that are 68 percent of the diameter of the wire in a given conventional spring, will have substantially the same rate, pitch diameter, solid height and average computed stress as the conventional spring.

Essential Details of Wire Strands

During the development work on stranded springs, the effects of the number of wires in the strand and the length of lay of the strand were investigated, the length of lay being the distance parallel to the strand axis in which a single wire makes one turn. It was determined that maximum fatigue life will result when three-wire strands are used in which the strand is so proportioned that the ratio of the length of lay to the strand diameter is between 5.0 and 5.5. Springs made from two-wire strands were found to have better fatigue life than equivalent conventional round wire helical springs; but the results were inferior to those obtained through the use of strands of three wires. Four or more wire strands are not stable unless a center wire is used. In a construction of four wires without a center wire, the wires are arranged ideally so that the centers of each wire section form a square; but the wires are unstable in that they are not well arranged to resist an external force, which rather easily deforms the square arrangement to a diamond shape. Strands containing a center-wire are being investigated further.

When a cross-section taken normal to the strand axis is composed of three circular wire sections in contact with each other, and when the centers of the three circular wire sections form an isosceles triangle, the diameter that circumscribes the three circular sections, will be 2.155 times the diameter of the wire. Actually the cross-sections of the wires are slightly elliptical instead of circular; and the strand diameter varies somewhat inversely with the length of lay. In three-wire strands where the ratio of the length of lay to the strand diameter is between 5 and 5.5, it will be found that the strand diameter is close to 2.18 times the wire diameter.

When wires are simply twisted together at a predetermined length of lay, the wires will recoil from the twisting and the wires will not be in contact thereafter. The fatigue test results of springs made from loosely stranded wire were distinctly inferior to those of springs in which the wires were in tight contact in the strand. To assure tight contact of the wires, the technicians of John A. Roeblings' Sons Company, who have contributed substantially to the success of the development work, found it essential that the individual wires be preformed; that is, given a helical twist just prior to being joined in the stranding operation.

The binding action produced in the wires of a stranded wire spring varies with the twisting moment, which is in turn produced by the axial force acting on the spring. It can be deduced by transient wave theory that the change in axial force is proportional to the change of velocity of an element of the spring as the displacement wave advances through the element. Therefore, the binding action and consequently the damping, in a stranded spring varies with the velocity of motion, which is the classic assumption for damping where mathematical analysis is concerned.

Under load-deflection tests the binding action in stranded springs produced little, if any, damping or frictional absorption of energy at low deflectional velocity. Fig. 2 shows load-deflection curves for the two springs of Fig. 3. There is no substantial difference between the hysteresis loops of the two springs.

In a simple spring system that has the physical attributes of mass and stiffness and in which the damping varies directly with velocity, the actual displacement under a

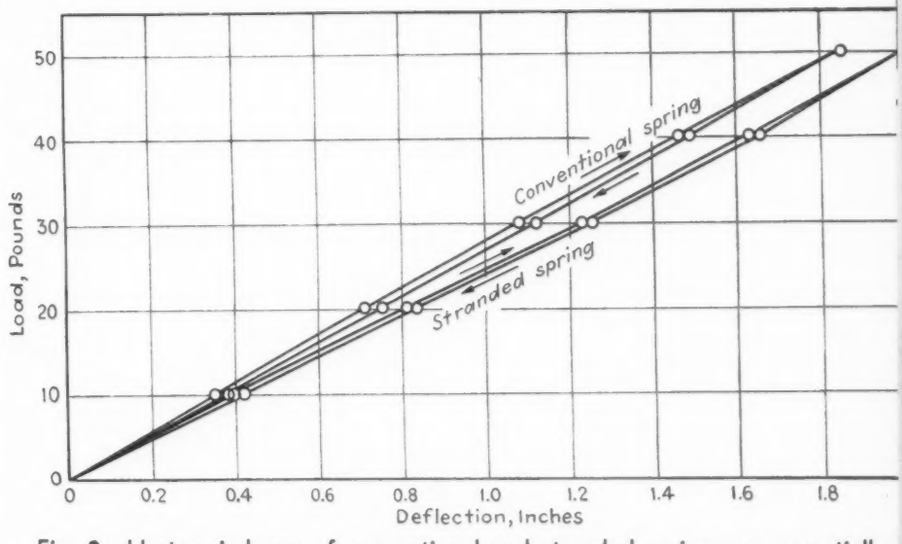
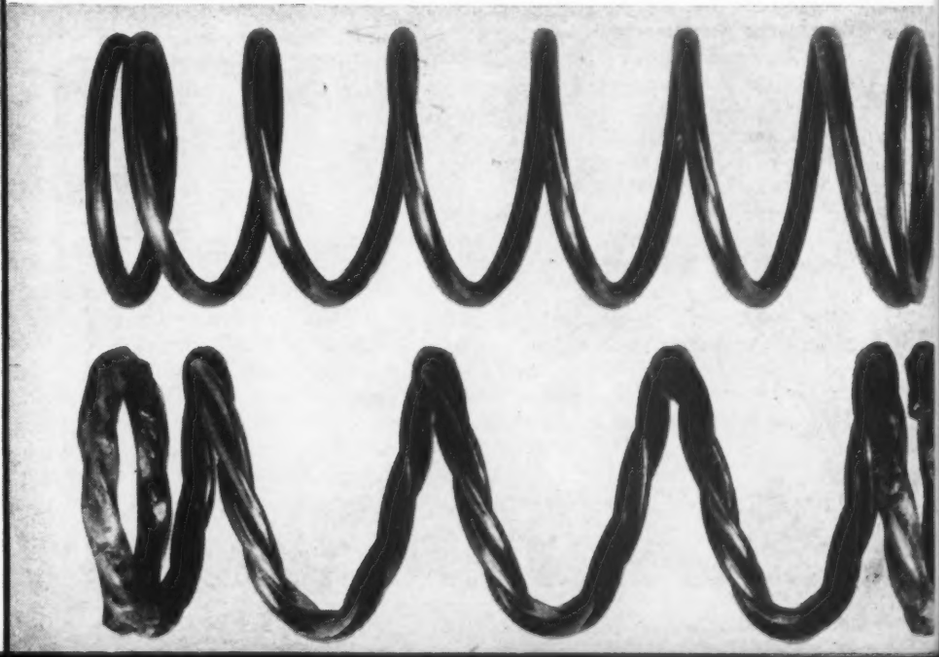


Fig. 2—Hysteresis loops of conventional and stranded springs are essentially same under static load-deflection tests. Fig. 3—Conventional spring made fr 0.102 in. dia. music wire and a 3-wire stranded spring made from 0.068 in. dia. w One coil at each end of stranded spring is brazed to permit ground, square ends



harmonic force will be much greater at certain frequencies of forced vibration than at other frequencies, either higher or lower. A measure of the intensity of the resonance effect is the magnification, or the ratio of the dynamic amplitude at the particular forced frequency to the deflection that would result from the application of a static force equal in magnitude to the maximum value of the applied harmonic force. The magnification has its maximum value at frequencies in the vicinity of the natural frequency for low and moderate values of damping, as may be seen in the curves of Fig. 4, which show the magnification effect for various degrees of damping.

Damping is expressed in terms of force per unit velocity. If the system has the critical value of damping, it will be brought to rest from a given initial displacement in a shorter time than if the damping were either greater or less than the critical value. The critical damping condition results when the damping in the system is numerically equal to twice the square root of the product of the mass of the system and the spring stiffness. In the curves of Fig. 4 the damping is expressed as the ratio of the damping coefficient to the critical value of the coefficient. It is notable that the greater the ratio of the damping coefficient to its critical value, the less becomes the magnification at resonance and the lower is the resonant frequency with respect to the natural frequency.

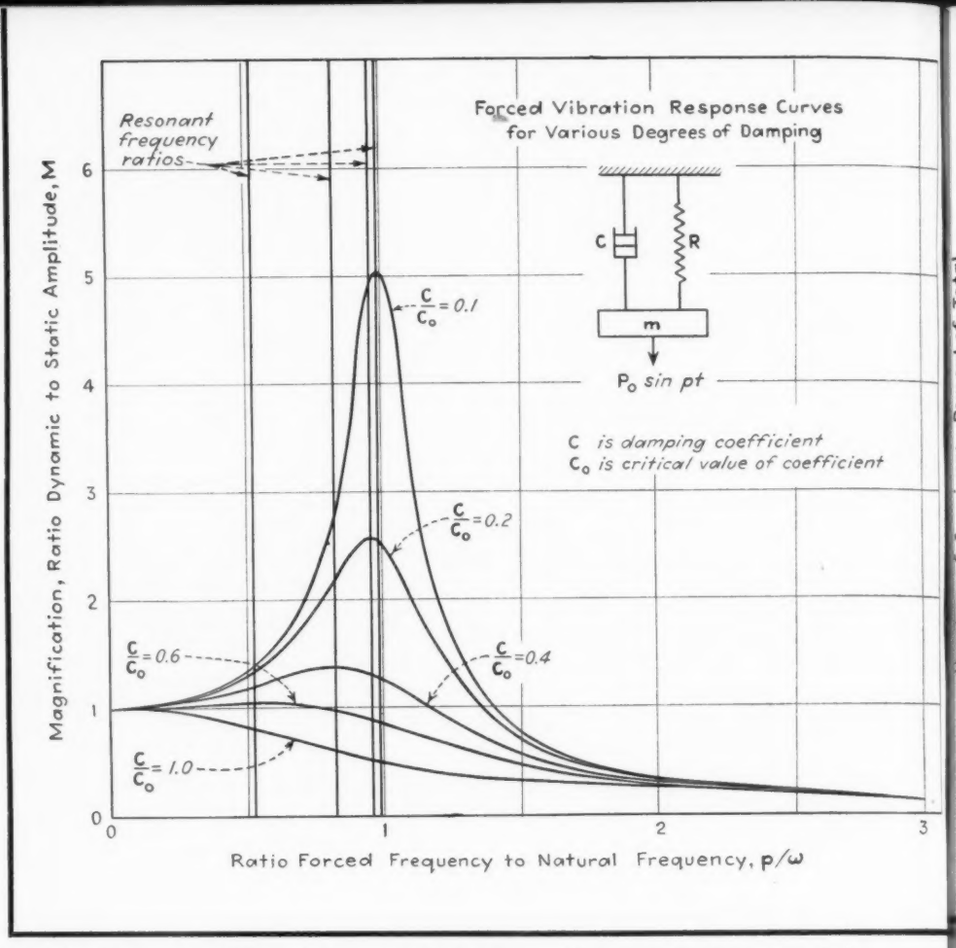


Fig. 4—Curves for different degrees of damping. The greater the ratio of the damping coefficient to its critical value, the less the magnification at resonance and the lower the resonant frequency with respect to the natural frequency.

Machine gun driving springs in general are quite long, soft as regards rate of deflection, and are subject to relatively great deflections. In consequence of these characteristics, the natural frequencies of driving springs are sufficiently low for the most part to make practical fatigue tests of the springs at their resonant frequencies, using a small constant displacement of one end of the spring for excitation. Fig. 5 shows a machine constructed to permit the resonant fatigue testing of these driving springs. The machine consists essentially of an electric motor, a variable speed control unit, a belt drive, flywheels, adjustable throw crank, and a vertical crosshead, which is connected to a means for actuating the spring under test. Because of the magnification effect at resonant operation, crank motion amplitudes of the order of 1/2 in. provide all the excitation necessary for the fatigue testing of most driving springs.

A novel feature of the machine construction is the arrangement provided for mounting the spring undergoing test. The test spring assembly comprises a cage to confine the spring and a centrally located piston and piston rod. The moving end of the spring engages the piston to which one end of the piston rod is attached. The other end of the piston rod is attached to the lower end of the vertical crosshead which in turn is fastened to a connecting rod and an adjustable stroke crank pin. The other (fixed) end of the spring supports the mass of the cage which confines the spring, the arrangement being such that extension of the piston rod with respect to the cage causes the spring to be compressed.

When conventional round-wire springs are operated at resonance it is found that the resonant frequency is extremely critical, a difference of but 40 to 50 r.p.m. making a marked change in the amplitude of the coils of the spring. Measurements of the coil amplitude at resonance in conventional springs indicate the presence of damping of the order of 10 to 15 percent of the critical value. Stranded springs equivalent to the conventional springs where rate of deflection, stress at solid compression, and loading are concerned, are found to be tuned more broadly at resonance. A much greater change in machine speed is required to produce a marked change in the resonant amplitude of the coils, and the stranded spring appears to have damping of the order of 25 to 30 percent of the critical value.

Resonant Fatigue Testing

The resonant testing machine shown in Fig. 5 was used extensively during the investigation of the characteristics of stranded springs, not only to evaluate the relative damping characteristics of driving springs but also to determine the relative fatigue lives. After the development of the proper technique, it was found that the testing of 30 or more driving springs in a lot would produce fatigue test results that could be correlated with firing test results.

Fatigue tests in the resonant testing machine were run until fracture occurred. No significant difference was noted in the amount of set that occurred during tests of conventional and stranded springs. In fire testing in guns, on the other hand, failure is usually judged to have occurred when either fracture has taken place or the loading of the spring has been decreased from set to a value below which the gun will not function satisfactorily. In general, conventional springs fail by fracture in fire testing, whereas stranded springs invariably fail because of set rather than fracture.

In Fig. 6 are two mortality curves that show the life expectancies of conventionally designed driving springs and equivalent stranded springs, on the basis of resonant fatigue testing. The average lives of the two designs as developed during the resonant testing were approximately 5,000 and 19,000 strokes, respectively. If the springs of Fig. 6 had been fatigue tested in a conventional slow-speed crank rig through the deflection range equivalent to the firing and the recoiled positions of the driving springs, it is probable that both would have withstood at least 100,000 strokes before failure and that there would have been little difference in the lives of the two designs.

Although resonant fatigue testing does

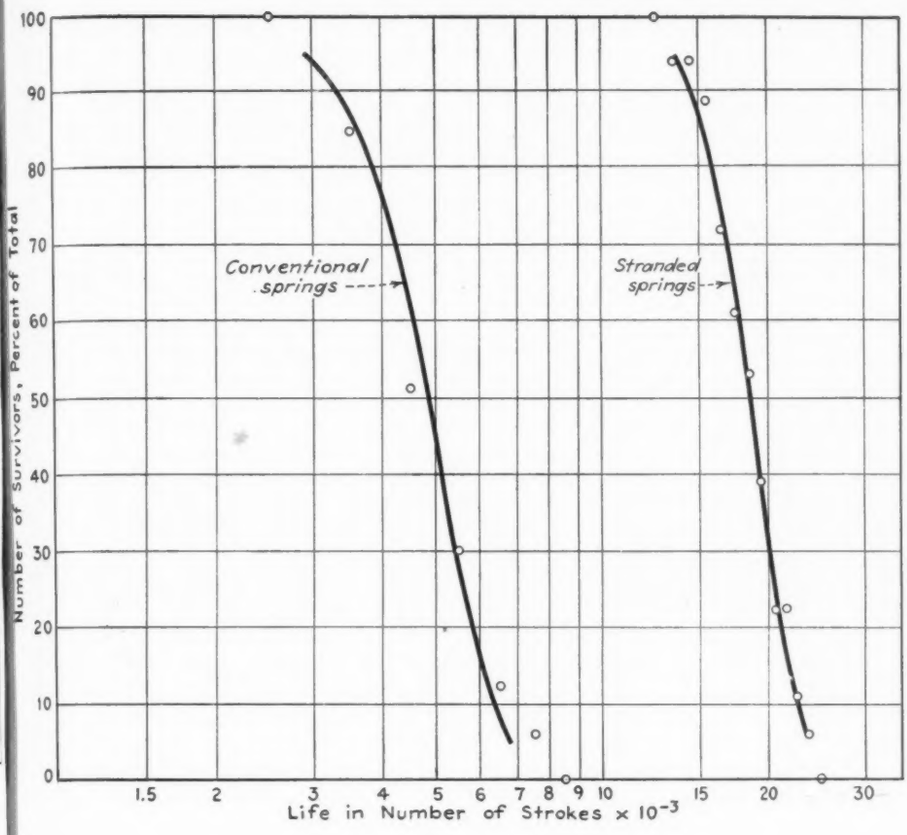


Fig. 6—Mortality curves comparing the life expectancies of a conventional spring made from 0.102 in. dia. music wire and a stranded spring made from 3-wires of 0.068 in. diameter. Comparative lives are about 5,000 and 19,000 strokes.

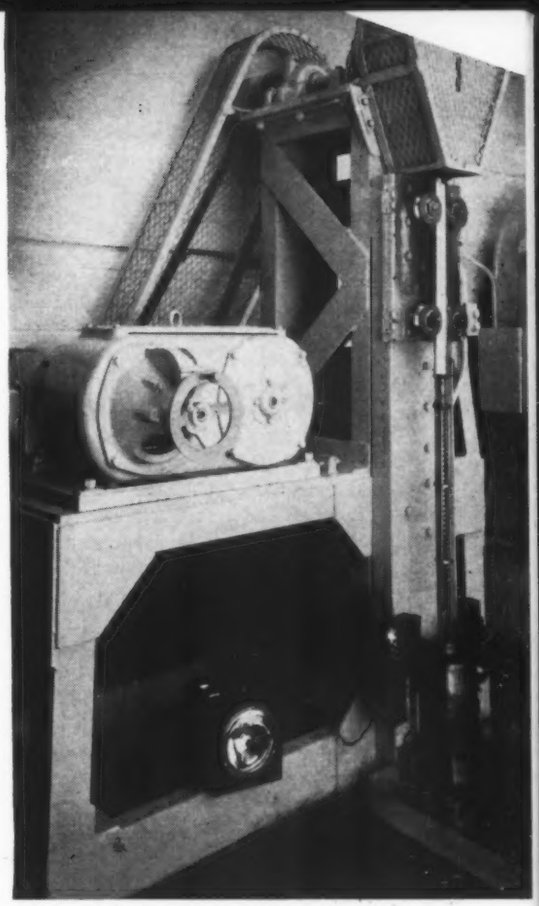


Fig. 5 — Testing machines of ½-in. amplitude give enough excitation for resonant fatigue testing.

not duplicate the action that the spring receives in a gun, the results can be correlated. Resonant fatigue testing has the advantage of being quick and inexpensive; and it proved itself valuable in the work on stranded springs where many series of tests were required to evaluate the relative influence on fatigue life of such factors as number of wires per strand, the length of lay of strand, materials and processing.

The conventional spring referred to in Fig. 6 was made from 0.102 in. dia. music wire; while the stranded spring was made from three music wires of 0.068 in. dia. stranded together so that the ratio of length of lay to stranded diameter was approximately 5.25. Both driving springs were designed to have an initial loading of 20 lb. when installed in a gun, and both had a rate of deflection of about 3 lb. per in. In the gun both springs are deflected from the initial installed position approximately 12-9/16 in. during recoil. In the resonant fatigue testing, the excitation amplitude was but 0.5 inch.

The average static stress-deflection characteristics of both springs in Fig. 6 were substantially the same when computed by Equation (1), the statically computed stress at solid deflection being approximately 150,000 lb. per sq. in. for both springs. The stranded spring does not have as good a space efficiency as a round wire spring; and, for that reason plus the effect of variations in strain along the undulations of the wire strands, the stresses in the stranded spring must truly be greater than those in the conventional spring, if all other things are equal and the spring is regarded as being loaded statically.

Since the damping effect in the stranded spring is dependent upon velocity, fatigue testing of stranded springs in relatively slow-speed, crank rigs may show little improvement, or even a decrease, in life for the stranded springs over conventional springs.

Transient Wave Phenomenon

The dynamic displacement of the coils of a machine gun driving spring is a transient wave phenomenon rather than a matter of resonant vibration. The amplitudes of displacement of the coils of the driving spring resulting from the firing of the gun may be greater or may be less than those observed in resonant testing, depending upon the relation between the effect of the velocity of the free end of the spring during firing and the effects of damping and excitation amplitude during resonant testing.

During recoil, the free end of a driving spring may attain velocities approximating 35 ft. per sec. in modern machine guns. When the displacement velocity is low the deflections of all the coils of the spring are assumed to take place simultaneously and instantaneously; and no substantial error is caused by the assumption. At high velocities, the coils of the spring deflect successively as the disturbance passes along the axis of the wire in the form of a wave; and, when displacement velocities are high as in driving springs, the actual progressive nature of the coil displacements must be taken into account. It can be demonstrated that, regardless of whether the spring is made from conventional round steel wire or from stranded steel wire, and provided that the pitch angle of the coils is not substantially in excess of 10 deg. a fair approximation of the T in milliseconds for the wave to travel from one end of the spring to the other can be obtained from

$$T = 0.0354 \frac{D^2 N}{d} \qquad (3)$$

As the wave of displacement passes through the coils of the spring immediately after firing, each element of the spring acquires the velocity of the free end upon the arrival of the wave at the element. The elements then tend to move at the acquired velocity until the motion is affected by the reflection of the wave from the fixed end of the spring. The initial reflection of the wave at the fixed end of the spring and the subsequent reflection from the free end are the causes of the extremely high dynamic stresses imparted to the spring.

Inherent damping in stranded springs subject to high displacement velocities is much greater than that in conventional

springs. It is believed that the greater damping is effective in absorbing energy so that the reflected wave in a stranded spring has a much lower energy content than the wave in a conventional spring. A substantial decrease in the energy content of the reflected waves would decrease the dynamic displacement of the coils of the spring, proportionately reducing the stress in the spring. The reduction of stress thus effected accounts for the increase of life available with the use of stranded springs.

To deal extensively with the transient wave phenomena affecting machine gun driving springs is beyond the scope of this article. According to transient wave theory the change of stress of an element of a spring varies directly as the change of velocity of the elements. The life of conventional springs would be expected therefore to vary inversely as some function of the velocity of displacement.

The damping effects of stranded springs become more effective as the velocity is increased. On that account stranded springs will appear more favorable in comparison with conventional springs when the displacement velocities are relatively high. In fact, if conventional driving springs are giving satisfactory life, say in the neighborhood of 20,000 to 30,000 rounds, the chances are that the displacement velocity is relatively so low that the damping effect in stranded springs is not of enough consequence to enable the stranded springs to show any appreciable improvement in life. On the other hand, if conventional springs have short lives, say in the neighborhood of 1,000 rounds, the displacement velocity is undoubtedly high enough to produce a strong damping effect in stranded springs, which will be effective in producing a most substantial increase in life.

In springs affected by transient wave phenomena the proportionality between the change in stress and the change in velocity is an important consideration. With the stress-velocity relationship in mind, beyond timing the spring design properly as regards the time for the wave to travel from one end of the spring to the other with respect to the time of recoil of the gun, the spring designer cannot further control the stress range through which the spring operates except through the provision of damping as in the stranded spring. From all evidence available to date, it appears that the matter of stress range is more critical in the fatigue life of springs than the stress level, or the mean stress in the operating cycle.

Materials and Manufacturing Processes

Music wire has proven to be the most satisfactory material used to date in stranded springs. Pretempered chrome-silicon wire has been used in a series of stranded springs; but the fatigue life was distinctly inferior to that of the music wire springs, and a substantial percentage of the alloy springs fractured during the coiling operation. The stranding operation and the subsequent coiling of stranded springs produce a severe state of strain in the component wire of the spring. Music wire has a much lower proportional elastic limit than pretempered wire, which accounts for the music wire being better able to yield and to adjust itself to the strains to which the material is subjected during the coiling process.

Stainless steel conforming to AISI No. 431 specification has been tried in a few applications of stranded springs. The material apparently does not have the strength of music wire, but a need for stainless steel exists in applications where the spring is subject to the influence of corrosive agents. The material is being investigated further. It is essential that the stainless steel springs be passivated after processing. This treatment involves heating the springs in an aqueous solution of 20 percent nitric acid and 1 percent sodium dichromate at 140 to 160 deg. F. for two hours.

In the conventional automatic coilers used in this country, the wire is in compression as feed rolls push it forward and around a stub arbor. It was feared that the compression forces in the wire during automatic coiling would loosen the wire strands, but so long as the ratio of the pitch diameter of the coils to the diameter of the wires in the strand is not smaller than 13, stranded springs can be coiled automatically. For smaller ratios of coil diameter to wire diameter the springs must be coiled on a conventional arbor-type coiler to avoid loosening of the strands.

As is the case for conventional music wire springs, it is necessary that stranded springs be stress relief annealed after coiling, that is, heated at approximately 450 deg. F. for a minimum of 30 min. It is also essential to coil the stranded springs somewhat higher than the finished springs and to remove the excessive height by pressing the springs from free to solid height a sufficient number of times to assure that subsequent compression to solid will produce no further reduction in free height. This pressing operation produces a beneficial residual stress pattern across the wire section in the unloaded spring. As the operation promotes a minimum of set during the subsequent operation of the springs, it is just as vital where stranded springs are concerned as it is for conventional springs.

Wave motion of the coils of a driving spring, which takes place during the firing of the gun, causes stresses to exist that may actually exceed the stresses produced by static compression to solid height. A spring that has been preset by pressing to solid height under static conditions will set additionally during firing in the gun because the actual stresses exceed those at which the spring was preset. This condition accounts for the large drop in the loading of drive springs during the initial rounds of firing. More adequate methods of presetting are required to minimize the initial set in the guns. The development of adequate presetting is by no means a simple problem, since the deflections are large and displacement velocities are high.

Shot peening was found to be beneficial in increasing the life of conventional driving springs by perhaps 50 to 60 percent. This increase is not as great as has been reported for such springs as automotive chassis suspension springs and automotive engine valve springs. This may be attributed to the fact that the dynamic stresses in the driving springs exceed the yield stress, which is not the condition of operation of other springs. Shot peening was not effective in increasing the fatigue life of stranded driving springs, the failure no doubt resulting from the helical twist of the wires in the strands preventing uniform shot impingement around each wire. But it was found that the individual shot particles would lodge in the strands. Subsequent dislodgement when the springs are installed in guns would be a hazard.

Significant features affecting the use of stranded wire springs in machine guns can be summarized briefly as follows:

1. The improvement in service available through the use of stranded springs in comparison with conventional springs results from the damping inherent in the stranded spring.

2. The damping in the stranded spring varies with velocity. The probability is that the greater the recoil velocity, the better the chance for a substantial improvement in life when the stranded spring is used in place of a conventional spring.

3. In light of current knowledge, 3-wire strands are recommended in preference to 2-wire strands. The 3-wire strands should be formed so that the ratio of length of lay to strand diameter lies between 5.0 and 5.5.

4. Music wire appears to be the most suitable material for use in stranded springs.

5. The stranded spring should be designed to have a minimum of mass. This in general involves basing the design of the spring upon relatively high average stress values.

The future will undoubtedly find the stranded spring in certain commercial applications where it can be used advantageously. There are not many instances where commercial mechanisms are required to operate at the relatively high velocities that are apparently necessary for effective damping in stranded springs. On this account, the stranded spring may continue to be significant chiefly for its military value in fast-firing small arms.

[Author's Note: The development work on stranded springs and the publication of this article were made possible through the encouragement and cooperation of the Ordnance Department, U. S. Army. The author is grateful particularly to Colonel R. R. Studler and Major C. E. Balleisen for their helpfulness and interest in the work and in the preparation of this article.]

Vibration Frequency Ratios Of Bottom Mounted Apparatus

J. N. MACDUFF
General Electric Company

THE ACCOMPANYING charts are a supplement to the article "Isolation of Vibration in Spring Mounted Apparatus—I," see page 106 of this number.

Data given in the charts can be used to obtain a quick estimate of frequencies in symmetrically supported bottom spring mounted apparatus. The curves are plotted from the following equations, in which

- a = horizontal distance from the mounts to the center of gravity parallel to the x axis, in.
- b = horizontal distance from the mounts to the center of gravity in the plane being considered, in.
- C = total horizontal dynamic spring constant in plane being considered, lb. per in.
- d = horizontal distance from the mounts to the center of gravity parallel to the y axis, in.
- h = vertical distance from the mounts to the center of gravity parallel to the z axis, in.
- K = vertical dynamic spring constant, lb. per in.
- r = radius of gyration about axis perpendicular to plane being considered, in.
- ω = natural frequency, radians per sec.
- ω_H = higher rocking frequency, radians per sec.
- ω_L = lower rocking frequency, radians per sec.
- ω_v = vertical frequency, radians per sec.
- ω_T = torsional frequency about the vertical axis, radians per sec.

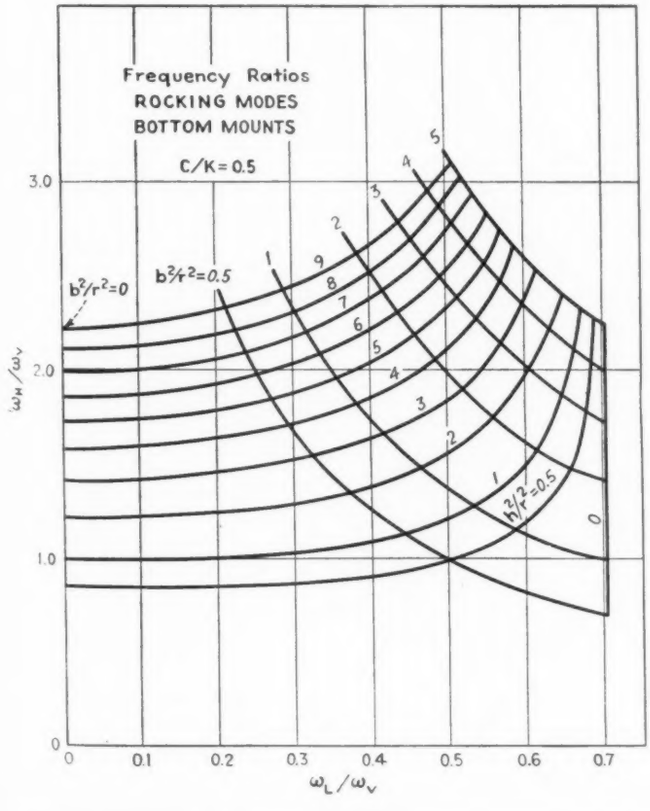
ROCKING MODES. The equation for the ratio of exciting frequency ω to the vertical frequency ω_v is

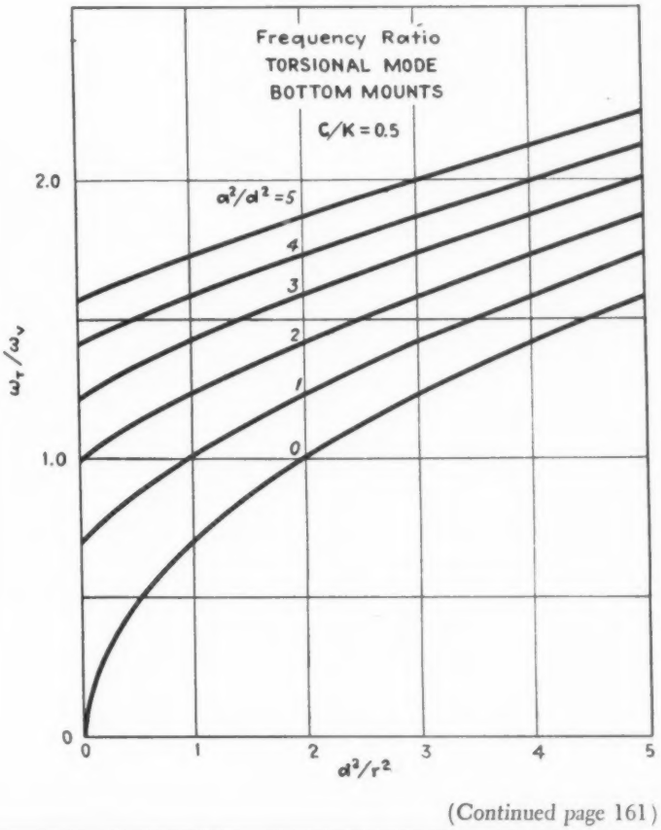
$$\frac{\omega}{\omega_v} = \left\{\frac{1}{2}\left(\frac{C}{K} + \frac{Ch^2}{Kr^2} + \frac{b^2}{r^2}\right) \pm \left[\frac{1}{4}\left(\frac{C}{K} + \frac{Ch^2}{Kr^2} + \frac{b^2}{r^2}\right)^2 - \frac{Cb^2}{Kr^2}\right]^{\frac{1}{2}}\right\}^{\frac{1}{2}}$$

The plus sign in the equation gives the higher rocking mode ω_H, the lower rocking mode ω_L is given by the minus sign.

TORSIONAL MODE. Curves are plotted for the condition that the horizontal stiffness C_x in the x direction is the same as the horizontal stiffness C_y in the y direction. The equation for the ratio of torsional frequency ω_T to the vertical frequency ω_v is

$$\frac{\omega_T}{\omega_v} = \sqrt{\frac{C}{K}\,\frac{(a^2 + d^2)}{r^2_z}}$$





(Continued page 161)

Sealed — AGAINST WEAR AND TEAR

Spring freshets would like to drive logs and debris through a beaver's domain, and autumn's drought tries to steal his home away. So the beaver long ago turned engineer. He *seals* his dam against upsets—slaps sticks, leaves and mud into stout masonry.

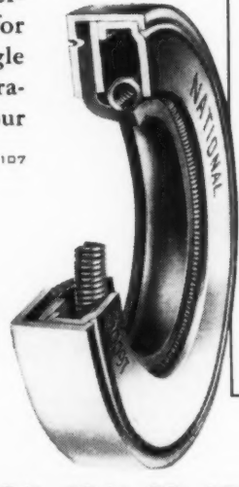
National Oil Seals work like beavers, at almost no cost, to keep lubricants *in* and hold dirt *out* of vital bearings and gears. Wherever shafts turn, in war machines or home industry, there's a job for Nationals. Built in the world's largest plants devoted to the single problem of oil retention, they can be "tailored" to fit any operation, large or small. There's a National engineer not far from your plant. Call him in.

1107

NATIONAL MOTOR BEARING CO., INC.

General Offices: Redwood City, Calif. • Plants: Redwood City, Calif., Van Wert, Ohio • Los Angeles, Calif. (Arrowhead Rubber Company)

NATIONAL
OIL AND FLUID SEALS

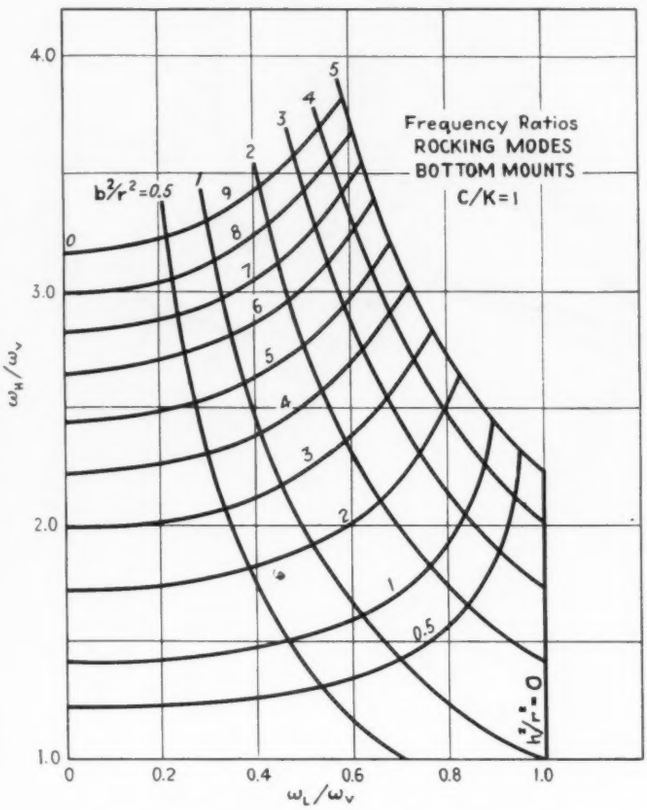


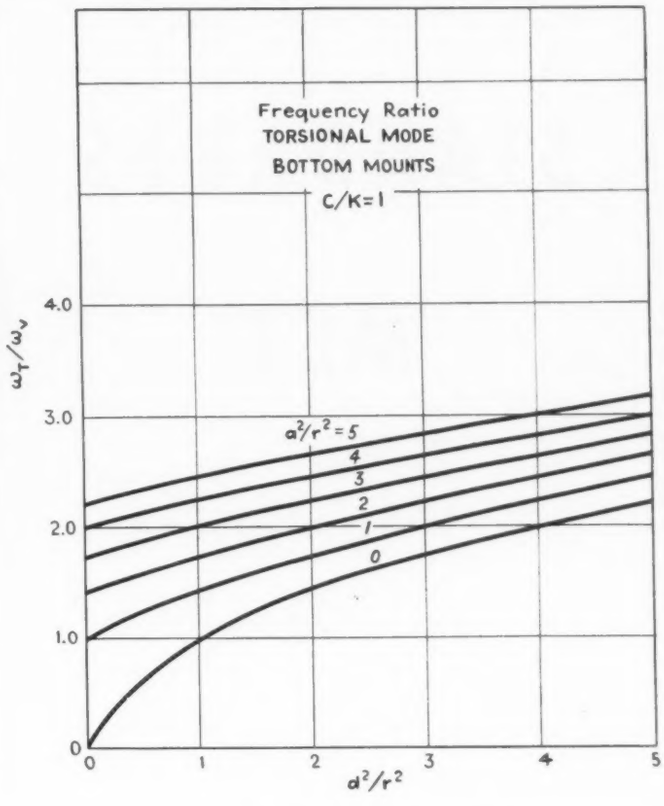
CALL IN A NATIONAL ENGINEER FOR RECOMMENDATIONS
No Obligation

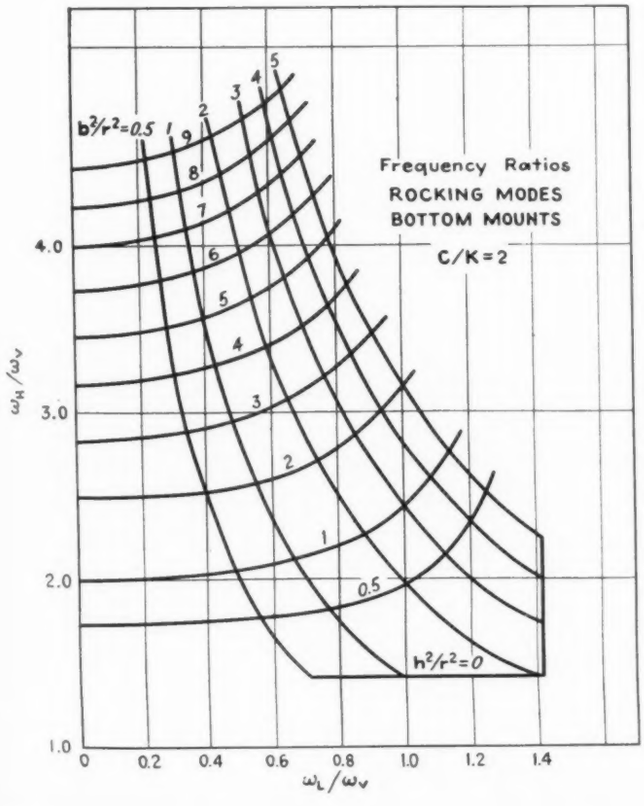
CHICAGO
135 S. LaSalle St., Central 8663
CLEVELAND
3091 Mayfield Rd., Yellowstone 2720
DETROIT
1026 Fisher Bldg., Trinity 16363
MILWAUKEE
1717 E. Kane Place, Lakeside 2838
NEW YORK CITY
122 E. 42nd St., Lexington 28260
PHILADELPHIA
401 N. Broad St., Bell-Walnut 6997
LOS ANGELES
2244 E. 37th St., Kimball 6384
REDWOOD CITY, CALIF.
Bdwy. and National, Rdwd. City 3400

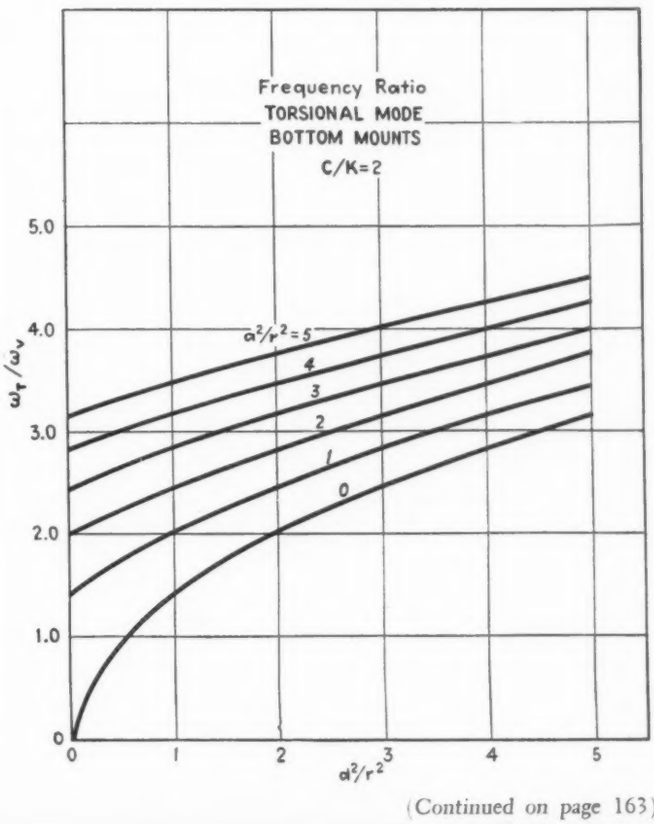
WHEREVER SHAFTS MOVE, THERE'S A NATIONAL OIL SEAL TO RETAIN THE LUBRICANT

Vibration Frequency Ratios of Bottom Mounted Apparatus (continued)





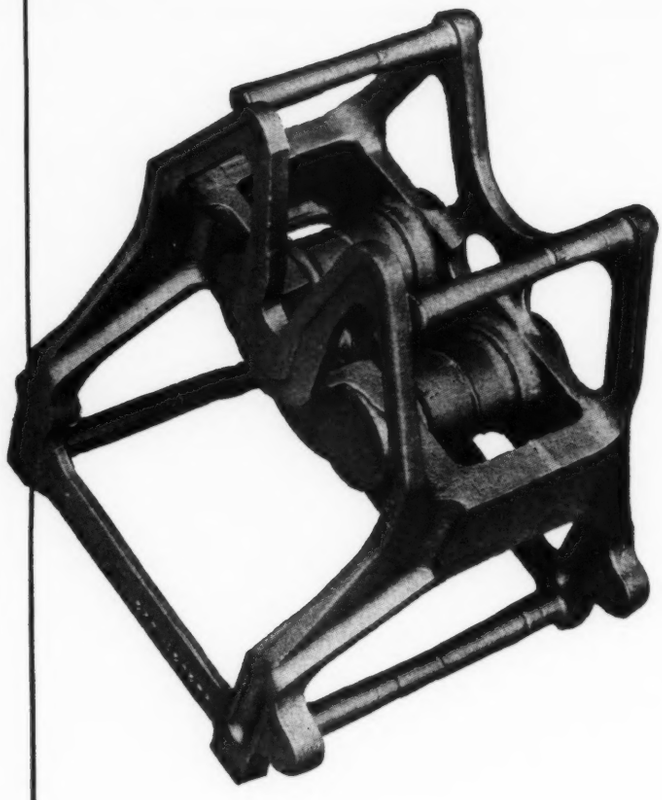




(Continued on page 163)

AIRCRAFT STANDARDS MET

... and Production Costs Reduced!



Designers of aircraft parts have two basic principles always before them—(1) Adequate strength and (2) Minimum weight.

And they have the same kind of cost problems that you do.

They know that patterns for castings cost less than dies, especially for short runs.

The Chief Process Engineer of a well-known aircraft manufacturer permits us to quote him as follows:

> "Intricate shapes can be cast much more readily than forged, and there are no objectional directional properties . . . machining time is saved because it is possible to cast to close contours . . . castings can be easily welded to other parts."

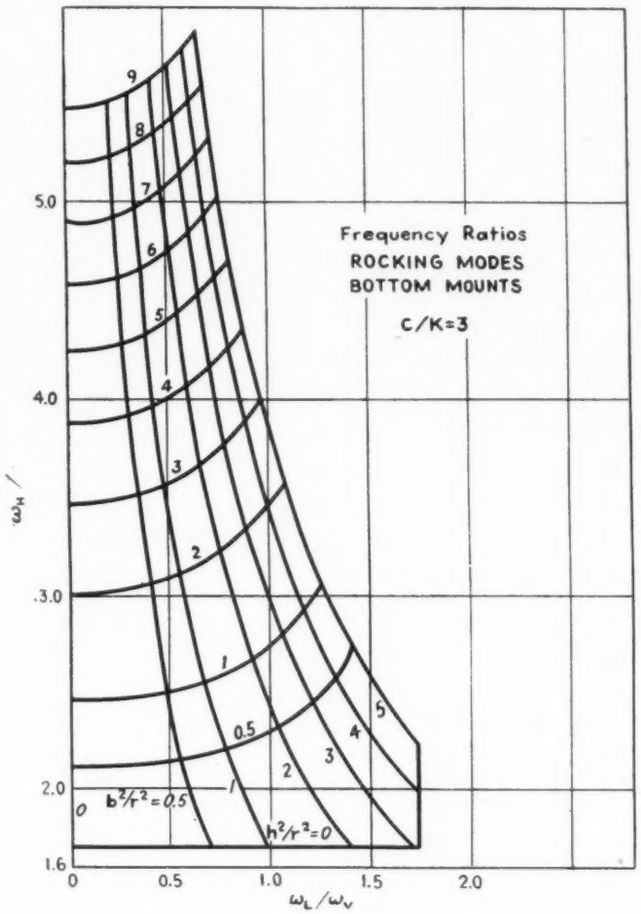
In designing parts for any machine, doesn't that just about cover all the requirements—strength, low cost, low machining expense, and metallurgical properties specified in advance?

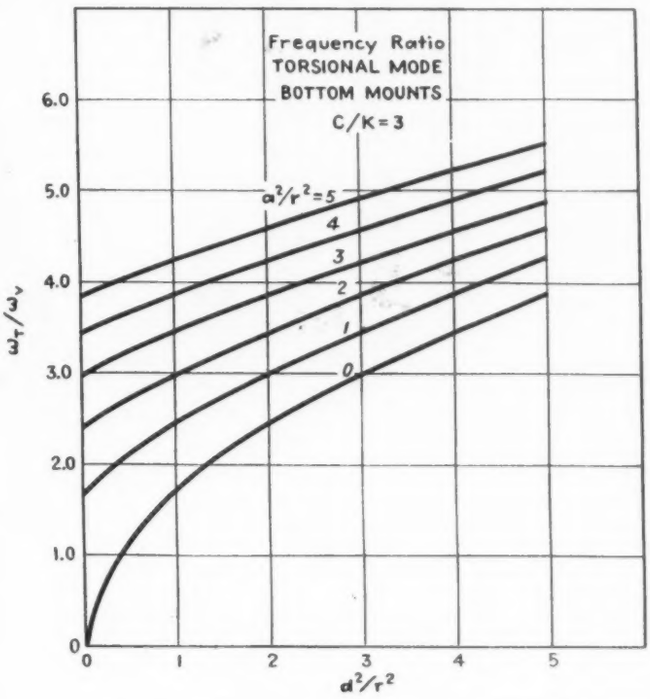
The first step in building an improved product, or in cutting costs, is to plan it that way—a steel castings engineer can help you. Steel Founders' Society, 920 Midland Building, Cleveland 15, Ohio.

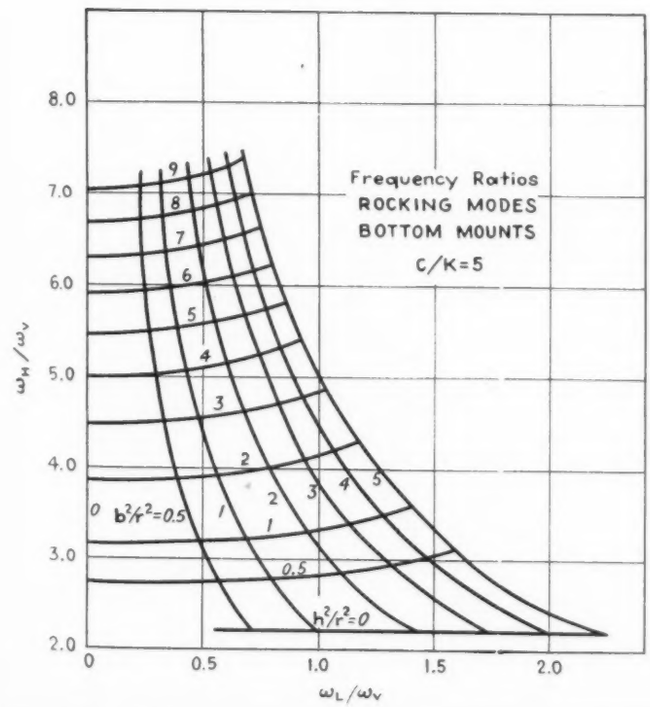
MODERNIZE AND IMPROVE YOUR PRODUCT WITH

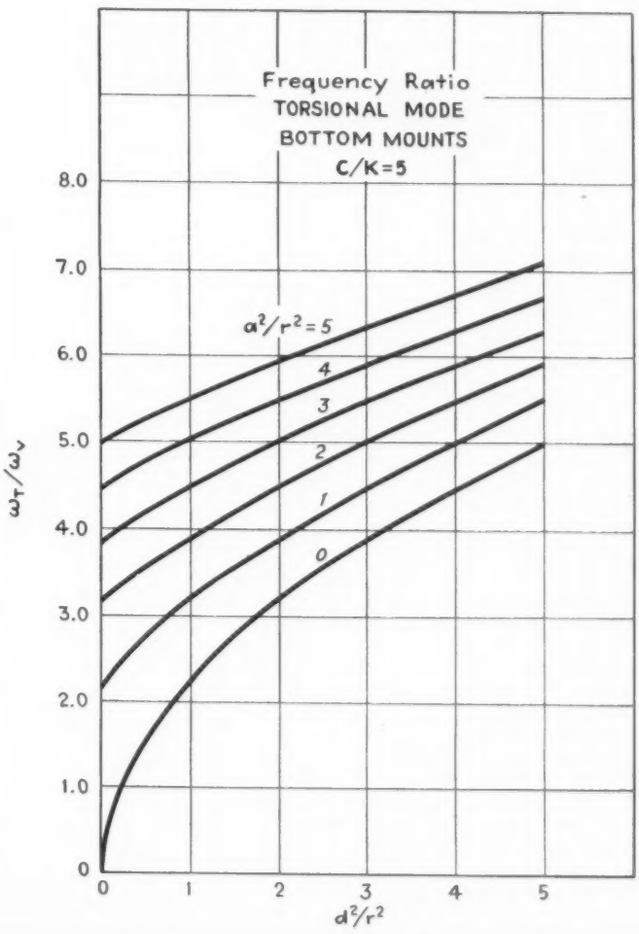
STEEL CASTINGS

Vibration Frequency Ratios of Bottom Mounted Apparatus (continued)









When the Armco salesman sends your order for special-purpose sheet steels to the Armco mills, he sets in motion a chain of "Quality Controls."

For more than 20 years supervisors at Armco have referred to these special prescriptions as "Q. C."

Summed up quickly, this is what Armco "Q. C." means to you: You get the *one right steel* for the products and equipment you make.

STARTS WITH SALESMAN

The salesman indicates the kind of steel you want—for what purpose it will be used and how it will be fabricated. Frequently he will ask for blueprints and other information about your application.

This is the reason: Back of him metallurgical and operating supervisors are ready with the "follow-through" to help insure Quality Control for the special-purpose sheets you buy. They weigh and sift requirements—determine the correct temper, annealing and the sequence of operations that will give your sheet steels the properties they need. Previous orders and similar applications are studied too.

All these data go on a routing card. From open-hearth to shipping department, this individual card accompanies your order. It is your assurance of a high "Q. C." in the Armco special-purpose steels that go into the products bearing your name. The American Rolling Mill Company, 3081 Curtis Street, Middletown, Ohio.

Export: The Armco International Corporation

SPECIAL PURPOSE ★ ARMCO ★ SHEET STEELS

THE AMERICAN ROLLING MILL COMPANY

NEW MATERIALS AND PARTS

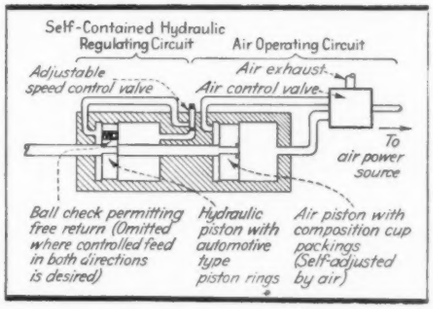
INDEX OF ITEMS

Product	Manufacturer	Page
Condenser	Timing Instrument Co.	169
Correction Block, Power Factor	Tobe Deutschmann Corp.	167
Coupling, Flexible Tube	The Warner Brothers Co.	169
Coverings, Plastic	Atlas Powder Co.	171
Cylinders	Logansport Machine Co.	165
Duct, Flexible	United States Rubber Co.	174
Equalized, Program	Cinema Engineering Co.	174
Fastener, Fluorescent Lamp	Tinnerman Products, Inc.	173
Fittings, Tube	Flodar Corp.	169
Floodlight	General Electric Co.	165
Head, Gage	The Yankee Precision Products Co.	169
Instrument, Multi-Use	Marion Electrical Instrument Co.	167
Laminant, Aluminum Foil	Paisley Products, Inc.	169
Laminates, Melamine	American Cyanamid Co.	174
Materials, Permanent-Magnet	General Electric Co	171
Pen, Drawing	RHM Mfg. Co.	174
Pump, Gearless	ECO Engineering Co.	169
Regulator	Control Division, Hagan Corp.	173
Relays, Plug-In	Sigma Instruments, Inc.	169
Resin, Thermosetting	E. I. du Pont de Nemours and Co.	171
Resistors	Ward Leonard Electric Co.	171
Switch, Cam-Lever	General Control Co.	169
Switch, Snap-Action	Arco Electric Co.	171
Tachometers, Switchboard	Metron Instrument Co.	167
Terminal, Solderless	Aircraft-Marine Products, Inc.	171
Tube, Cathode Ray	Allen B. Du Pont Laboratories, Inc.	169
Turrets, Flexible Gear	Brooks Equipment Corp.	174
Valve, Check	Greer Hydraulics, Inc.	173
Valve, Non-Metallic 3-Way	Grove Regulator Co.	167
Valves, Micrometer	Standard Instruments Co.	167

Cylinders

Logansport Machine Co., Logansport, Ind.

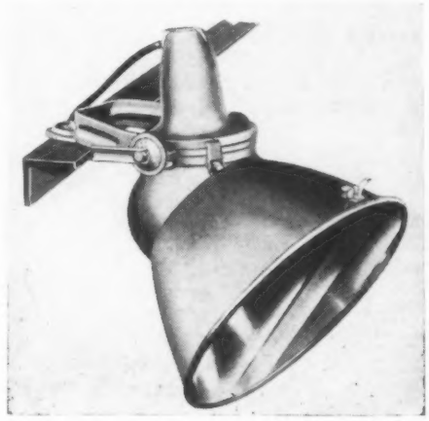
"Air-Draulic" Cylinders are made with separate air and hydraulic pistons assembled as an integral unit on a common piston rod. No hydraulic power unit is required. Rod movements are powered by the air cylinder, which may be controlled by any type of 4-way air valve. As the piston rod with its two pistons is moved, oil flows between the chambers of the hydraulic cylinder, which are connected externally in a self-contained circuit. An adjustable, built-in speed control valve in this circuit regulates the flow of oil and hence the speed of the piston rod movement. Cylinders can be furnished for controlled feed with rapid return in either direction. Skip feed movements can also be provided through cam valves in the hydraulic circuit. Five standard mounting types, foot, clevis, center-line, rod-end flange and blind-end flange are available. Cylinders are made in 4 standard sizes from 3 to 8 in. bore, with any length of stroke to 5 ft. The air piston is built for operation at pressures to 150 lb. per sq. in. The hydraulic cylinder has 3 automotive-type piston rings and a centrifugal cast barrel. No tie rods are required on the hydraulic cylinder, and the end cover is attached by cap screws. Alternate air bleeders are provided. The air cylinder is brass-lined steel tubing and the molded composition packings are self-adjusted by the air. Large air inlets permit pressure to act on the entire piston area at one time.


Self-Contained Hydraulic Regulating Circuit
Air Operating Circuit
Adjustable speed control valve
Air exhaust
Air control valve
To air power source
Ball check permitting free return (Omitted where controlled feed in both directions is desired)
Hydraulic piston with automotive type piston rings
Air piston with composition cup packings (Self-adjusted by air)

Floodlight

General Electric Co., Schenectady 5, N. Y.

Designated as Type L-69, this floodlight is adaptable for all uses that require lamps of 750- to 1500-watt sizes. The forward edge of the aluminum reflector is spun over the rim of the glass, making a dirt-, weather-,



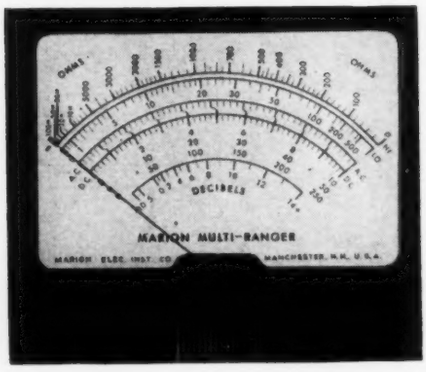
and insect-proof seal. The 3/16 in. Tufflex tempered plate glass door is heat and impact resistant. Access to the interior of the reflector and to the lamp is gained by unfastening two toggle latches and lifting the aluminum socket housing from the reflector. The housing can be removed without disturbing the position of the reflector, and the latches are positioned so that the socket housing cannot be improperly remounted. A clip is mounted on the side of the socket housing so that the removed assembly can be clipped to the trunnion bracket in a convenient position. To facilitate aiming the center of the beam when adjusting the floodlight for coverage of area, a blade sight is located on the reflector and a notch sight on the socket housing. A pointer and degree scale are provided on one trunnion for setting of the floodlight. Normal servicing requires no movement of the unit. Total

movement, both in elevation and azimuth, is 180 deg. Located on the same trunnion as the elevation scale is a built-in clamping-bolt wrench that is used for adjusting and locking the reflector. All materials and finishes are corrosion-proof. The weight of the Type L-69 floodlight with lamp is 19 pounds.

Multi-Use Instrument

Marion Electrical Instrument Co., Manchester, N. H.

The Multi-Ranger is available in 3½, 4½ and 8½-in. sizes and each size is interchangeable electrically. The basic sensitivity of the instrument is 400 microamp. and the

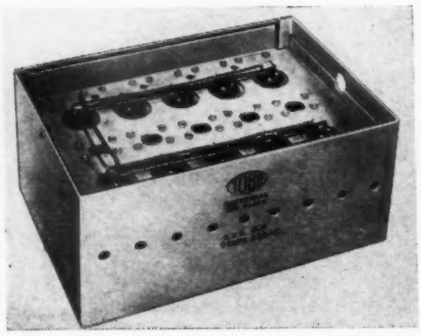


internal resistance is 500 ohms, plus or minus 1 percent. The scales are printed in 3 colors for quick identification and cover a full 100 deg. The instrument can be used as a 2,500 ohm-per-volt or as a 1,000 ohm-per-volt meter; as a milliammeter; low and high range ohmmeter and as a 1,000 ohm-per-volt a.c. voltmeter. The scale ranges, as normally supplied, include: 0-10-50-250 d.c. volts, 0-10-50-250 a.c. volts, 0-500 ohms and minus 10-megohms, minus 10 to plus 14 db. By use of the proper multiplier, the 0-10 voltmeter scale can also be used for 0-1,000 volts. The scales are printed in red, black and green. Circuits are supplied with each instrument to provide instructions for the construction of single or multi-range equipment and all component values are shown on the circuits.

Power Factor Correction Block

Tobe Deutschmann Corporation, Canton, Mass.

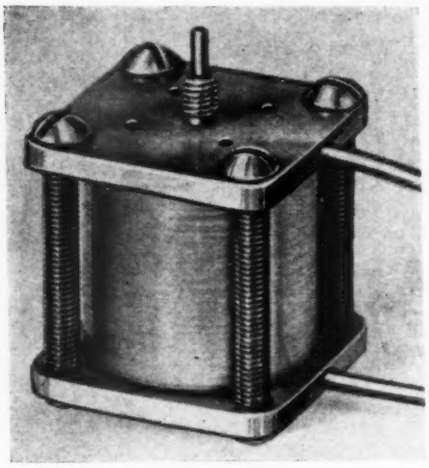
Constructed of 10 mfd. center-tapped units bolted into a rigid steel housing, this unit provides to 2 kva. at 2300 volts, 50-60 cycles. It can be connected for either single phase or three-phase operation; individual sections can be disconnected for accurate load balancing; and elements can be removed and replaced if necessary. The capacitor sections are oil-impregnated, are hermetically sealed in oil-filled metal cases, and are capable of continuous operation at temperatures to 75 deg. C. The assembly is contained in a 16 gage steel housing, having provision for conduit entrance at one end. A removable cover, held in place by screws, gives access to the section terminals; solder-lug terminals permit direct connection of circuit conductors up to No. 12 wire. The unit measures 9 3/8 x 6¼ x 14 inches.



Micrometer Valves

Standard Instruments Co., 15 Elkins St., South Boston 27, Mass.

Claimed to withstand vibration and mechanical abuse, these valves are made of non-corrosive metals. The flow of air and other gases can be varied over the range of 0.2



to 60 cu. in. per min. with a pressure drop across the valve of 15 lb. per sq. in. Under the same conditions, the flow of water and light liquids can be varied from 0.04 to 10 cc. per min. The valve measures 1½ in. square and 2 in. high.

Switchboard Tachometers

Metron Instrument Co., 430 Lincoln St., Denver 9, Colo.

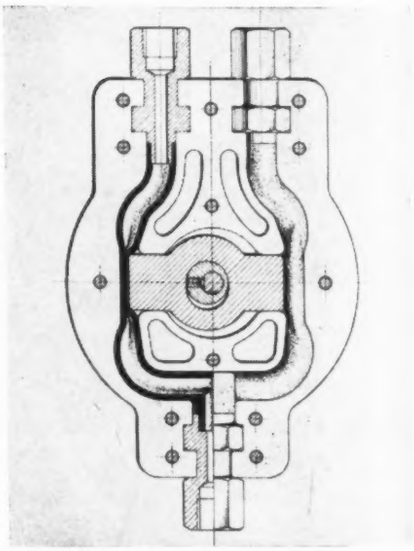
The head consists of a contact-making mechanism that is connected to the indicating unit by an electric cable of any length to 1,000 ft. These oscillating contacts periodically charge a condenser through a d.c. milliammeter. The circuit constants are chosen so that the milliammeter does not correspond to each charge but reads the average current. The circuit is designed so that the current is exactly proportional to the r.p.m. of the spindle that operates the contacts. Accuracies are claimed to range

from ¼ of 1 percent. Limited-range models are available for continuously monitoring specific speeds. Models with multiple heads for monitoring several spindles simultaneously or in succession are available as well as continuously recording models. A variety of heads is available for fitting any type of machine. Tachometers can be single range or multi-range. Operation is from the 115 volt a.c. power line. No vacuum tubes or warm-up required. Stabilized against line voltage changes.

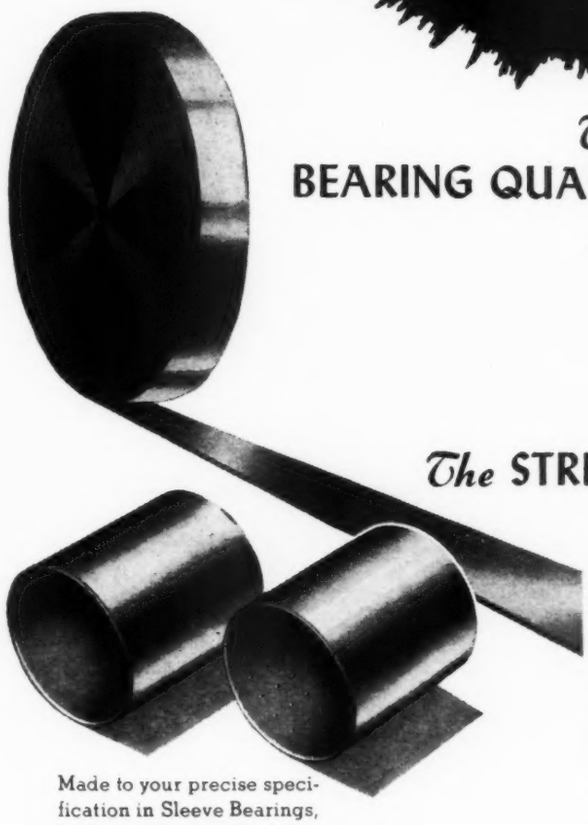
Non-Metallic 3-Way Valve

Grove Regulator Co., 65th & Hollis Sts., Oakland 8, Calif.

Using a flexible molded synthetic rubber tube, encased within a molded plastic body, the Grove Flex-tube three-way valve is designed for handling all types of fluids, in-

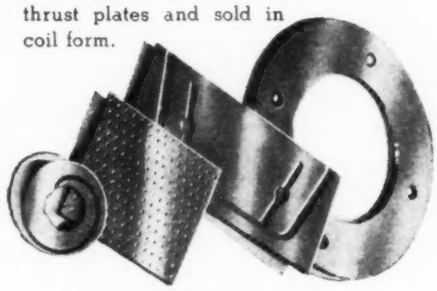


Something NEW in Bearings



The BEARING QUALITIES of Pre-Cast Bearing Bronze on The STRENGTH of PATENTED Steel

Made to your precise specification in Sleeve Bearings, fabricated into washers, thrust plates and sold in coil form.



. . . Write TODAY for this new literature on Johnson BRONZE-ON-STEEL.

Here is a new and unusual Sleeve Bearing material that combines the excellent bearing characteristics of a high grade bronze alloy with the strength of steel. It enables manufacturers to increase speeds and loads . . . to give longer bearing life with smooth operation . . . plus greater resistance to shock and to wear. Pre-Cast Bearing BRONZE-ON-STEEL produces a thin wall, laminated type of bearing. The fabricating process, essentially a series of stamping and forming operation, provides accuracy and precision. It is low in cost, particularly in long production runs.

In addition to its wide use as Sleeve Bearings, Pre-Cast BRONZE-ON-STEEL serves many other important applications in industry. Many concerns use it for stampings, washers, guide strips and other flat pieces. For such purposes we can supply it in coils with a maximum width of 5-1/2" and a range of thickness from 1/32" to 3/32".

Excellent delivery is now possible on both finished bearings, parts or coils. Why not investigate the possibilities of using BRONZE-ON-STEEL in your product? A Johnson Engineer will be glad to show you how and to explain its many advantages. There is a Johnson Bronze man as near as your phone. Why not call him in TODAY?

JOHNSON BRONZE
SLEEVE BEARING HEADQUARTERS
The MOST COMPLETE SLEEVE BEARING SERVICE in the WORLD
508 S. MILL STREET NEW CASTLE, PA.

SENSITIVE LOW-POWER RELAYS in a newly improved design

FOR USE ON AC AND DC

Engineering superiority in every mechanical and electrical detail makes Struthers-Dunn Type 112 Relays far and away "tops" for sensitivity and durability for low-power operation on the order of a few milliwatts • A "fool-proof" micrometer adjustment assures exceptionally reliable setting of the contact spring • All parts are of low-inertia, quick-acting design • Contacts are easy to adjust and stay "put" once adjusted • Coils are well insulated and vacuum impregnated • These new relays are built throughout for easier installation, higher sensitivity, longer life • Available in single-pole double-throw and double-pole double-throw contact combinations.

Write for Data Bulletin 112.

S-D
5,327 RELAY TYPES

STRUTHERS-DUNN

STRUTHERS-DUNN, Inc., 1321 Arch St., Phila. 7, Pa.

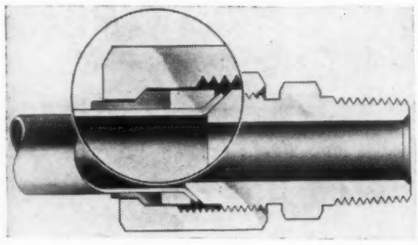
ATLANTA • BALTIMORE • BOSTON • BUFFALO • CHICAGO • CINCINNATI • CLEVELAND • DALLAS
DENVER • DETROIT • HARTFORD • INDIANAPOLIS • LOS ANGELES • MINNEAPOLIS • MONTREAL
NEW YORK • PITTSBURGH • ST. LOUIS • SAN FRANCISCO • SEATTLE • SYRACUSE • TORONTO

cluding gases, chemicals and liquids. Manual operation, by an over-center cam, opens and closes the ports at each half turn of the handwheel. Available in 1/8 and 1/4 in. pipe size, these valves are furnished for working pressures to 250 lb., and 150 deg. F. maximum temperatures.

Tube Fittings

Flodar Corp., 331 Frankfort Ave., Cleveland, Ohio.

Known as "Grip Tube", this fitting has a heat-treated steel sleeve, the rear end of which is slotted to form spring fingers. Tightening of the nut forces the forward end of the sleeve against the tube flare, sealing the fitting. Further tightening of the nut contracts the segmental fingers of the sleeve around the tube, thus gripping the tube uniformly. Vibration is absorbed by



the cantilever spring support. It is claimed that the heat-treated sleeve and the flare seal joint will withstand pressures in excess of tube ratings, and that the tube will not expand at the flare nor the sleeve expand in tightening. The tube fittings are available in ¼ to 2-in. tube sizes. The nut will slide around short tube turns.

Aluminum Foil Laminant

Paisley Products, Inc., 1770 Canalport Ave., Chicago 16, Ill.

A synthetic thermo-plastic resin emulsion adhesive designed for foil lamination. Recommended primarily for roll applicator machines, this adhesive will handle all grades of aluminum foil to cellophane, acetate, glassine, bond, kraft, sulphite, chip-board and other materials.

Cathode-Ray Tube

Allen B. Du Mont Laboratories, Inc., 2 Main Ave., Passaic, N. J.

The type 3JP tube is designed for oscillographic and other applications requiring a small, short tube with high light output and deflection sensitivity. The focusing electrode current under operating conditions is negligible, and the 2 in. neck and diheptal base provide insulation between electrode leads for high-altitude installation. For applications where deflection voltages are under suitable control, the 3JP is directly interchangeable with the 3FP. Equipment

using the 3BP may be adapted to use the 3JP by providing for connecting the intensifier electrode of the 3JP either to the second anode potential or to a higher potential than the second anode.

Flexible Tube Coupling

The Warner Brothers Co., Spiratube Div. Dept. 45, Bridgeport 1, Conn.

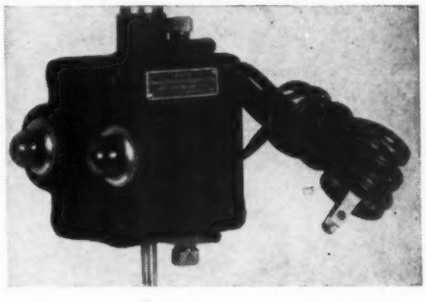
The Warner coupling is built into the tubing, and consists of a flat spring steel collar. It can be compressed to slip inside the end of another section and then released. The sections are disconnected by

compressing the inner spring steel collar and withdrawing the male end. The couplings are covered with long-fiber duck fabric, processed fire-resistant and coated with a thermoplastic. There is no exposed metal inside or out. Spiratube is furnished in standard diameters from 3 to 16 in. and in lengths of 10, 15 and 25 feet.

Gage Head

The Yankee Precision Products Co., 50 Bartholemew Ave., Hartford, Conn.

An electronic self-contained gage head for direct connection to 110 volt circuit. Gage has plus and minus lights that operate within a gage setting of 0.00001 in. The head can be attached to a support or stand or



arranged to suit any specific application. The gage spindle is claimed to be frictionless and contacts are made without multiplication leverage. Close adjustment of plus and minus setting is accomplished through a differential screw, and means provided to lock the setting. The complete unit is approximately 2¾ in. square.

Plug-In Relays

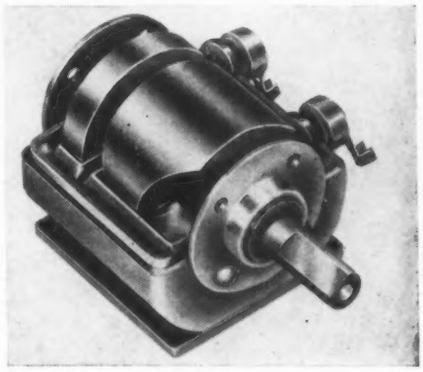
Sigma Instruments, Inc., Boston, Mass.

A plug-in type relay weighing 3 oz. and measuring 1½ x 1½ x 1⅞ in., and an unin-closed type weighing 2⅝ oz. and measuring 1 x 3/32 x 2 3/16 in. Minimum input requirements are 20 milliwatts for d.c. types and 0.1 volt-amperes for a.c. types. Contacts are s.p.d.t., and will handle to 15 amp. on low voltage d.c. or 1 kw. incandescent lamp load at 115 volts a.c. Beryllium-copper armatures and contact springs, and spring reed-type armature hinges with low reluctance gaps are used in these units.

Condenser

Timing Instrument Co., 106 Spring St., New York 12, N. Y.

The Cam-Rotor Variable Fluid Condenser is claimed to eliminate acoustical feedback, and is covered to provide complete shielding together with a dustproof and moisture-proof seal. The Cam-Rotor has solid barrel-cam rotors. Utilizing one moving part per stage, the rotors are mounted on a low-pass plastic shaft and are separated from



the single-unit solid stator. Into this clearance a synthetic fluid dielectric is added. The sealed-in construction of the complete unit prevents seepage of the dielectric fluid, and provides a pre-tracked and permanently adjusted assembly.

Gearless Pump

Eco Engineering Company, Dept. 75, 12 New York Ave., Newark, N. J.

A double-impeller gearless pump, with standard 1 in. connections. A built-in driveshaft bearing and base eliminates side-pull when the pump is powered by a belt-drive and

How to design better gears in 10 minutes

SUPPOSE you were asked to design a product—almost any kind of product requiring right angle reduction gears—and told to design it to last longer, and cost less. And then you were told to get it done quickly, use gears on which you can get fast delivery and "don't do any guessing".

Well, at that point you could either pick up your hat or say "that's easy"—and prove it. For all you would have to do is pull out your copy of "Cone-Drive Standard Gear-Sets", pick the gear-set you need for the particular job and class of service and specify it on the drawing by tool number. All the gear designing, calculations as to bearing sizes, etc., have already been done for you.

Last longer? Cone-Drive gearing's exclusive larger tooth contact, more teeth in contact and self-lubricating action mean lower unit pressures and vastly reduced wear.

Cost less? With Cone-Drives you can cut gear size as much as ⅓, for the same load capacity, reducing cost of both gears and housings, etc.

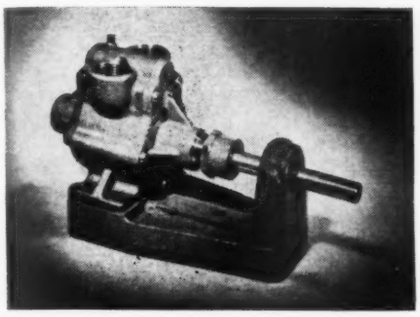
Quick delivery? Cone-Drive standard gear sets are now carried IN STOCK in blank form, ready for final gear cutting.*

Write today for your copy of "Cone-Drive Standard Gear Sets". Ask for Catalog #700.

*Cone-Drive Standard Gear Sets are stocked in ratios from 5:1 to 70:1 and for requirements ranging from 0.06 hp at 100 rpm to 600 hp at 2400 rpm.

CONE DRIVE

CONE-DRIVE DIVISION **MICHIGAN TOOL COMPANY**
7171 E. McNichols Road, Detroit 12, U.S.A.



pulley. The impellers are claimed to pass sand, grit, filings, or sludge without stalling, jamming, or stripping and without damage to the bronze pump body. The overall dimensions are 10¼ x 4¼ x 5¾ in. The capacity varies from 7.5 gal. per min. at 600 r.p.m. to 23 gal. per min. at 1800 r.p.m. The pump can be mounted at any angle, and will pump in either direction. No adjustments or lubrication are needed, except on the external drive-shaft bearing.

Thermosetting Resin

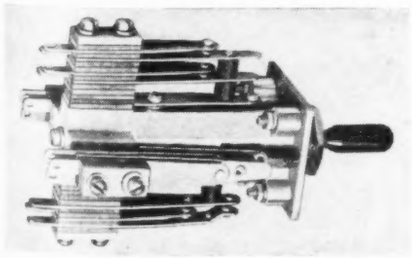
E. I. duPont de Nemours & Co., Wilmington 98, Del.

A resin, known as BCM, is claimed to have excellent bonding properties and high resistance to heat. The liquid resin requires a short curing period and low laminating pressure, and can be used as an impregnating and laminating resin either by itself or mixed with a polymer. In the cured state, BCM has no odor and is resistant to most organic materials. Absorption of water, and other common solvents such as acetone and ethanol, is from 1 to 2 percent. The resin is thermosetting, and has a permanent high-gloss finish. Thin veneers to which BCM has been applied can be bent without crazing or peeling the resin. A range of colors can be obtained by adding oil-soluble dyes or pigments to the resin. Cast BCM can be worked with high-speed tools by the same methods used for methacrylates.

Cam-Lever Switch

General Control Co., 1200 Soldiers Field Road, Boston 34, Mass.

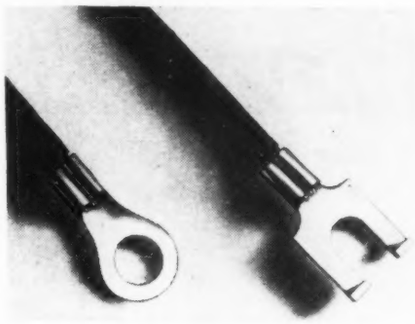
The Model MCF 5-position cam-lever switch has single hole mounting of the switch frame to the panel and single bolt assembly of the contact block to the switch frame. The switch is locking or non-locking in all positions except the center position, which is always locking. The motion of the switch from the center to all switching positions is a straight line. The silver contacts are riveted to nickel-plated, phosphor-bronze contact springs, and all parts are non-corrosive. The contacts are rated at 10 amp. 125 volts, a.c. (non-inductive load).



Solderless Terminal

Aircraft-Marine Products, Inc., 1591R N. Fourth St., Harrisburg, Pa.

These terminals, attached with press dies, can be installed at a rate in excess of 600 an hour. The connections are neat, clean, uniform, and can be inspected visually.



Budget Line terminals are small and compact; the crimp permits use of short terminals without sacrifice of electrical or mechanical characteristics. The crimping action is claimed to give maximum inside surface contact with the conductor.

Plastic Covering

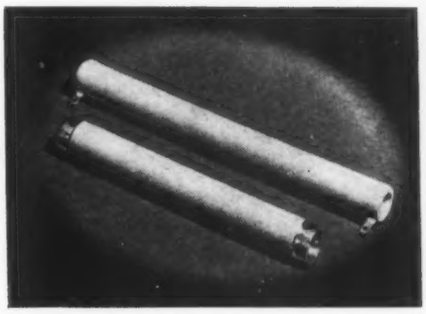
Atlas Powder Co., Zapon Div., Stamford, Conn.

Brevon, an air-tight plastic covering, protects machines, equipment and other products with a tough, non-inflammable, anti-corrosion film. The covering is claimed to have a life span of 20 years. It resists a tensile pull of 2,000 lb. per sq. in. and provides a low vapor transmission rate under high pressure. It retains all its qualities through a temperature range of 40 deg. F. below zero to plus 200 deg. F. Brevon is applied by spraying. Objects with projecting parts are first covered with a latticework of tape strips over which the Brevon webbing solution is applied.

Resistors

Ward Leonard Electric Co., Mount Vernon, N. Y.

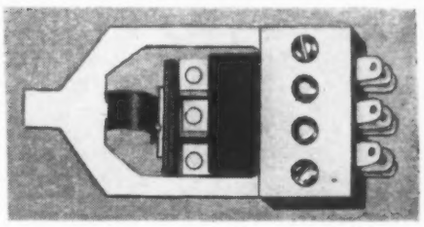
Vitrohm "M" vitreous enameled resistors are available in ferrule, tab and screw terminal types with power ratings from 8 to 155 watts and capable of operation continuously at 275 deg. C. Resistance values are obtainable in sizes from 0.1 to 80,000 ohms with resistance tolerances for one ohm and above of plus or minus 5 percent specified values. Vitrohm "M" resistors are claimed to have excellent thermal shock, momentary overload and salt water immersion characteristics.



Snap-Action Switch

Arco Electric Co., 1310 Superior Ave., Cleveland 14, Ohio.

A three-pole, open-blade, snap-action switch for handling three circuits simultaneously is claimed to have a mechanical life expectancy of more than ten million operations. Its



overall size is 3 x 1 3/8 x 1/2 in. It is rated at 10 amp. at 125 volts a.c., or 5 amp. on 230 volts. Operating pressure runs from 12 to 18 oz. for the return type construction and 4 to 8 oz. for the set type construction. Made for normally open or normally closed circuits—single throw or double throw.

Permanent-Magnet Materials

General Electric Co., Schenectady, N. Y.

Five permanent-maget materials, Cunico, Cunife, Vectolite, Alnico 12 and Silmanal, for industrial uses where small, lightweight magnets formed in intricate shapes are required. Cunico is an alloy of copper, nickel and cobalt. Cunico magnets are made from rod, strip or wire stock, and are furnished only in their final shapes because they are age-hardened in the manufacturing process. Cunico is malleable, ductile and machinable. Cunife is a copper-nickel-iron alloy having all the physical properties of Cunico, but differing in that it has directional properties and must be magnetized only along the direction in which the material has been cold-worked, to obtain highest magnetic quality. Cunife magnets are made from wire stock in round, square or rectangular form. Cunife wire can be flattened to make thin, narrow shapes. Vectolite is a hardened, sintered combination of iron

BOSTON GEAR POWER TRANSMISSION EQUIPMENT . . . . . AND COMPONENT MACHINE PARTS

IN 63 CITIES FROM COAST TO COAST

Write, Phone, or Call on any one of these BOSTON GEAR DISTRIBUTORS for complete data on all products

AKRON, OHIO
Manufacturers Rubber & Supply Co.
ALBANY, NEW YORK
Sager-Spuck Supply Co.
ALLENTOWN, PENNSYLVANIA
Wm H. Taylor & Co., Inc.
ATLANTA, GEORGIA
J. M. Tull Metal & Supply Co.
BALTIMORE, MARYLAND
Carey Machinery & Supply Co.
BOSTON, MASSACHUSETTS
Chandler & Farquhar Co., Inc.
BRIDGEPORT, CONNECTICUT
Hawley Hardware Co.
BRONX, NEW YORK
Bronx Hardware & Supply Co.
BROOKLYN, NEW YORK
H. L. Dickie
BUFFALO, NEW YORK
Root, Neal & Co.
BURLINGTON, NORTH CAROLINA
Kester Machinery Co.
CANTON, OHIO
Manufacturers Rubber & Supply Co.
CHARLOTTE, NORTH CAROLINA
Mathews-Morse Sales Co.
CHICAGO, ILLINOIS
Berry Bearing Co.
Boston Gear Works, Inc.
Chicago Pulley & Shafting Co.
Power Transmission Equipment Co.
CINCINNATI, OHIO
Queen City Supply Co.
CLEVELAND, OHIO
Boston Gear Works, Inc.
Mau-Sherwood Supply Co.
DALLAS, TEXAS
Geo. J. Fix Co.
DAVENPORT, IOWA
Standard Bearings Co.
DAYTON, OHIO
Klinger-Dills Co.
DENVER, COLORADO
Denver Equipment Co.
Western Belting & Packing Co.
DES MOINES, IOWA
Standard Bearings Co.
DETROIT, MICHIGAN
Chas. A. Strelinger Co.
EVANSVILLE, INDIANA
Bearings Service Co., Inc.
HARTFORD, CONNECTICUT
Silliter-Holden, Inc.
HIGH POINT, NORTH CAROLINA
Kester Machinery Co.
INDIANAPOLIS, INDIANA
Indianapolis Belting & Supply Co.
Vonnegut Hardware Co.
JACKSONVILLE, FLORIDA
S. B. Hubbard Co.
KANSAS CITY, MISSOURI
Ellfeldt Machinery & Supply Co.
LOS ANGELES, CALIFORNIA
Andrews Hardware & Metal Co.
Garrett Supply Co.
LOUISVILLE, KENTUCKY
Industrial Equipment Co.
MEMPHIS, TENNESSEE
Lewis Supply Co.
MIAMI, FLORIDA
Miami Parts & Spring Co.
MILWAUKEE, WISCONSIN
Western Iron Stores Co.
MINNEAPOLIS, MINNESOTA
R. C. Duncan Co.
NASHVILLE, TENNESSEE
Keith, Simmons Co., Inc.
NEWARK, NEW JERSEY
Squier, Schilling & Skiff
NEW BRITAIN, CONNECTICUT
Smith & Klebes, Inc.
NEW HAVEN, CONNECTICUT
C. S. Mersick & Co.
NEW ORLEANS, LOUISIANA
R. J. Tricon Co.
NEW YORK, NEW YORK
Morris Abrams, Inc.
L. C. Biglow & Co., Inc.
Boston Gear Works, Inc.
NORTH QUINCY, MASS.
Boston Gear Works, Inc.
OAKLAND, CALIFORNIA
C. W. Marwedel
PEORIA, ILLINOIS
Illinois Bearing Co.
PHILADELPHIA, PENNSYLVANIA
Boston Gear Works, Inc.
Maddock & Co.
PITTSBURGH, PENNSYLVANIA
Somers, Fitler & Todd Co.
PORTLAND, OREGON
Woodbury & Co.
PROVIDENCE, RHODE ISLAND
Machine Parts Corp.
RICHMOND, VIRGINIA
Apex Machine Mfg. Co.
ROCHESTER, NEW YORK
John M. Forster Co.
ST. LOUIS, MISSOURI
Colcord-Wright Machinery & Supply Co.
ST. PAUL, MINNESOTA
R. C. Duncan Co.
SAN FRANCISCO, CALIFORNIA
C. W. Marwedel
SEATTLE, WASHINGTON
Cragin & Co.
SIOUX CITY, IOWA
Standard Bearings Co.
SOUTH BEND, INDIANA
Bearings Service Co., Inc.
SYRACUSE, NEW YORK
Syracuse Supply Co.
TAMPA, FLORIDA
Lenfestey Supply Co.
TOLEDO, OHIO
The Ohio Belting & Transmission Co.
TRENTON, NEW JERSEY
Wiley-Hughes Supply Co.
WATERBURY, CONNECTICUT
White Supply Co.
WILKES-BARRE, PENNSYLVANIA
Holmes-Metallic Co.
WINSTON-SALEM, N. CAROLINA
Kester Machinery Co.
WORCESTER, MASSACHUSETTS
W. M. Steele Co.

★ ★ ★

CANADA, MONTREAL
Renold Coventry Ltd.
CANADA, TORONTO
Renold Coventry Ltd.
CANADA, VANCOUVER
Renold Coventry Ltd.

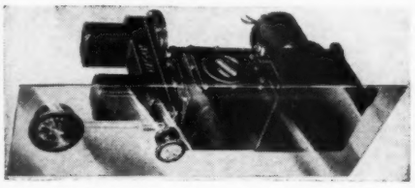
BOSTON GEAR WORKS, INC. NORTH QUINCY, MASSACHUSETTS

rust and cobalt oxide mixed when in powder form. Vectolite magnets are light, non-metallic, and non-conductive. They have a high resistance to demagnetizing forces. Alnico 12 is made up of aluminum, nickel, cobalt, iron and titanium. Alnico 12 magnets are cast, and must be ground to shape. Silmanal is ductile and malleable and can be punched, machined, rolled, or ground. It can be made in rod, strip or wire form and has a high intrinsic coercive force.

Regulator

Control Division, Hagan Corp., Hagan Building, Pittsburgh, Pa.

The Type 2-SO Regulator is designed to regulate the ratio of pressure or differential pressures. The operating range of this device is from 0.10 in. water column to 5 lb. per sq. in. The regulator is designed for the

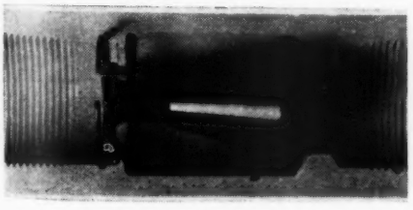


control of suction, pressure or flow ratio in any gas or air flow system where control is required; control of fuel-air ratio where close regulation is necessary, and control of gas or air flow proportions in industrial processes.

Check Valve

Greer Hydraulics, Inc., 454 18th St., Brooklyn 15, N. Y.

A valve housing, a hollow aluminum alloy poppet, an aluminum alloy poppet guide, a valve spring, and a retaining ring, comprise this unit. The valve is claimed to have completed a 50,000 cycle test, fully open to fully closed at 2,000 lb. per sq. in. without appreciable wear on the poppet or the seat.

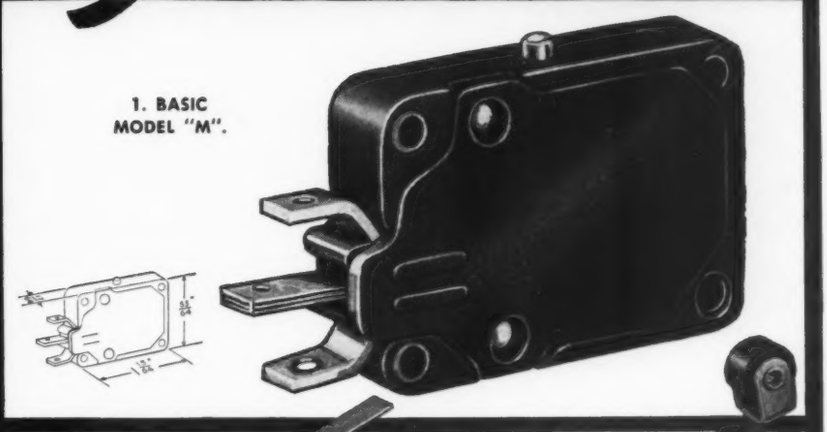


Fluorescent Lamp Fastener

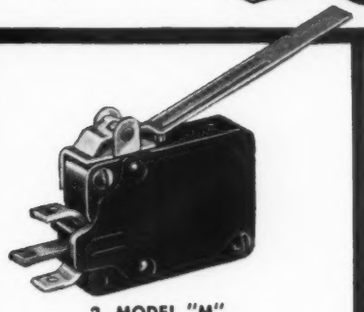
Tinnerman Products, Inc., 2041 Fulton Road, Cleveland 13, Ohio

A spring-steel fluorescent lamp fastener designed with speed nut prongs to afford a spring tension grip. The turned-up ends of spring arms hold the nut in place and extruded collar butts against the back of the vertical slot in the socket to lock the nut in screw-receiving position. This one fastener may be used with any socket of this type. Made of SAE 1060 tempered steel finished with soluble oil dip. Used with standard 6-32 machine screws. Also

ACRO'S *Sturdier* MODEL "M"



1. BASIC MODEL "M".



2. MODEL "M" WITH A-18 LEAF BRACKET.

3. MODEL "M" WITH A-18-M ROLLER LEAF BRACKET.

In keeping with the ever-widening demand for small ACRO Snap Action Switches, built with the patented Beryllium Rolling Spring and with the experience gained in building hundreds of thousands, ACRO now adds a sturdier, more durable housing for its popular long life Model "M".

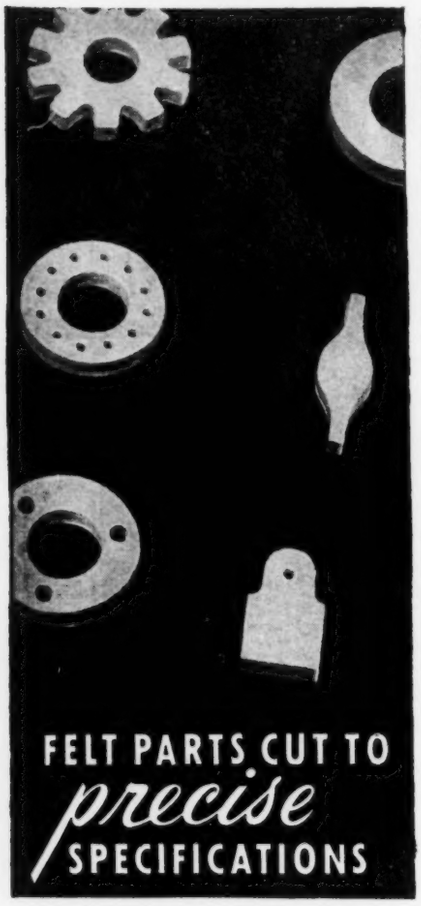
NEW FEATURES

1. ***New stronger molded case*** — cover recessed into case, clear of the four 3/32" mounting holes. • **2.** ***Sturdier barriers between terminals,*** affording generous electrical clearances. • **3.** ***Heavier solder terminals*** with .082" terminal holes for easier wiring. • **4.** ***Greater compactness*** for multiple assemblies—four can be mounted in a space of *less than 1⅛"*.

This better built, better performing switch is made with single pole, single or double throw contacts—rated at 10 amps. 125 volts A. C. Can be fitted with leaf actuators illustrated above. For immediate help on your switch problems, send full details of operating characteristics required and proposed assembly.

ACRO ELECTRIC COMPANY

1310 SUPERIOR AVENUE • CLEVELAND 14, OHIO



Skilled operators and Booth-designed machinery combine to give you the utmost in accuracy of die-cut mechanical felt parts. Specifications are adhered to precisely. No deviations in size or thickness . . . the last felt part in any one lot is an exact duplicate of the first.

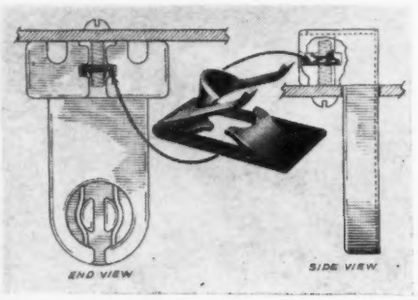
Prompt deliveries are routine at Booth and your order, small or large, receives interested attention.

●

APPLICATION CHART AND SAMPLE KIT . . . ***contains swatches of S.A.E. felt types, with specification tables. Write for it. (No sales follow-up.)***

THE BOOTH FELT COMPANY
475 19th Street — Brooklyn 15, N. Y.
736 Sherman Street — Chicago 5, Ill.
2320

Booth
TRADE MARK
PRECISION CUT FELT PARTS



used on any plastic or die-cast product where a blind assembly fastener can be provided with a recess to hold the nut.

Flexible Duct

United States Rubber Co., Rockefeller Center, New York, N. Y.

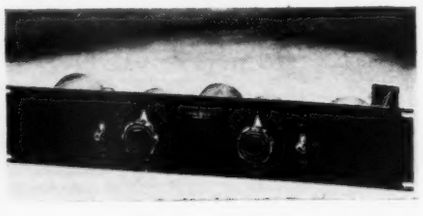
Multi-Flex ducts are light and durable and are claimed to withstand temperatures from 350 deg. F. to 70 deg. below zero. They are

made of glass and asbestos fabrics impregnated with synthetic rubber and plastics. No wire reinforcements are employed. Flexibility is obtained by corrugations.

Program Equalizer

Cinema Engineering Co., 1510 W. Verdugo Ave., Burbank, Calif.

For use in the broadcast or recording field, this program equalizer provides a variety of controls for equalization, attenuation or sound effect filtering. Graduated in 2 db. steps, high and low ends of the sound spectrum can be regulated over a range of 16 db. attenuation and 12 db. equalization. Attenuation is peaked at 100 cycles on the low end. A key selector permits switching high frequency peak equalization to 3, 5, or 10 kc. A cut-out key, enabling pre-setting, is provided with a fixed pad to compensate for insertion loss in the "out" position, enabling the equalizer to be cut in or out at will with no change in the overall level.

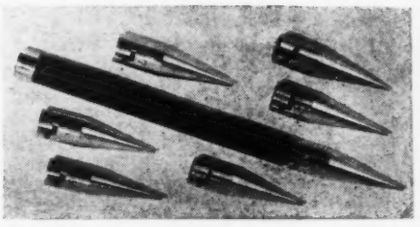


The unit is designed with a constant "K" circuit, resulting in no change of impedance, signal level or wave distortion over the entire range of the instrument. Type 4031 Equalizers are supplied on a 3½-in. panel to fit a standard relay rack.

Drawing Pen

RHM Mfg. Co., 44 Court St., Brooklyn 2, N. Y.

The "Drafkap" produces a continuous line 30 to 40 ft. in length with one filling and can be used for line work, lettering, in stencils and as a contour pen. The pen

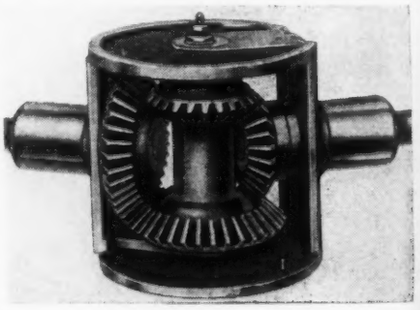


has a steel core with a plastic handle and is equipped with seven interchangeable and numbered brass caps for varying the thickness of line, from 0.018 to 0.065 in. depending upon the thickness required.

Flexible Gear Turrets

Brooks Equipment Corp., 217 Hudson St., Hoboken, N. J.

Designed for connecting shafts at any angle between 0 and 95 deg. on either side of zero angle. The bevel gears, attached to shafts supported in hinged housings, permit the shafts to oscillate and rotate simultaneously. Power capacities are claimed to



be consistent with standard power transmission practice for shafts from ¾ to 1½ in. dia. Two types of brackets are offered for supporting the gear boxes.

Melamine Laminates

American Cyanamid Co., 30 Rockefeller Plaza, New York, N. Y.

Sandwich laminate construction of resin impregnated decorative and barrier sheets, with a resin impregnated kraft core pressed into a rigid board under heat and pressure. Abrasion resistant surface, low moisture absorption, ease of cleaning, and excellent electrical properties are claimed for these laminates.